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OF THE

GEOLOGICAL SURVEY

OF

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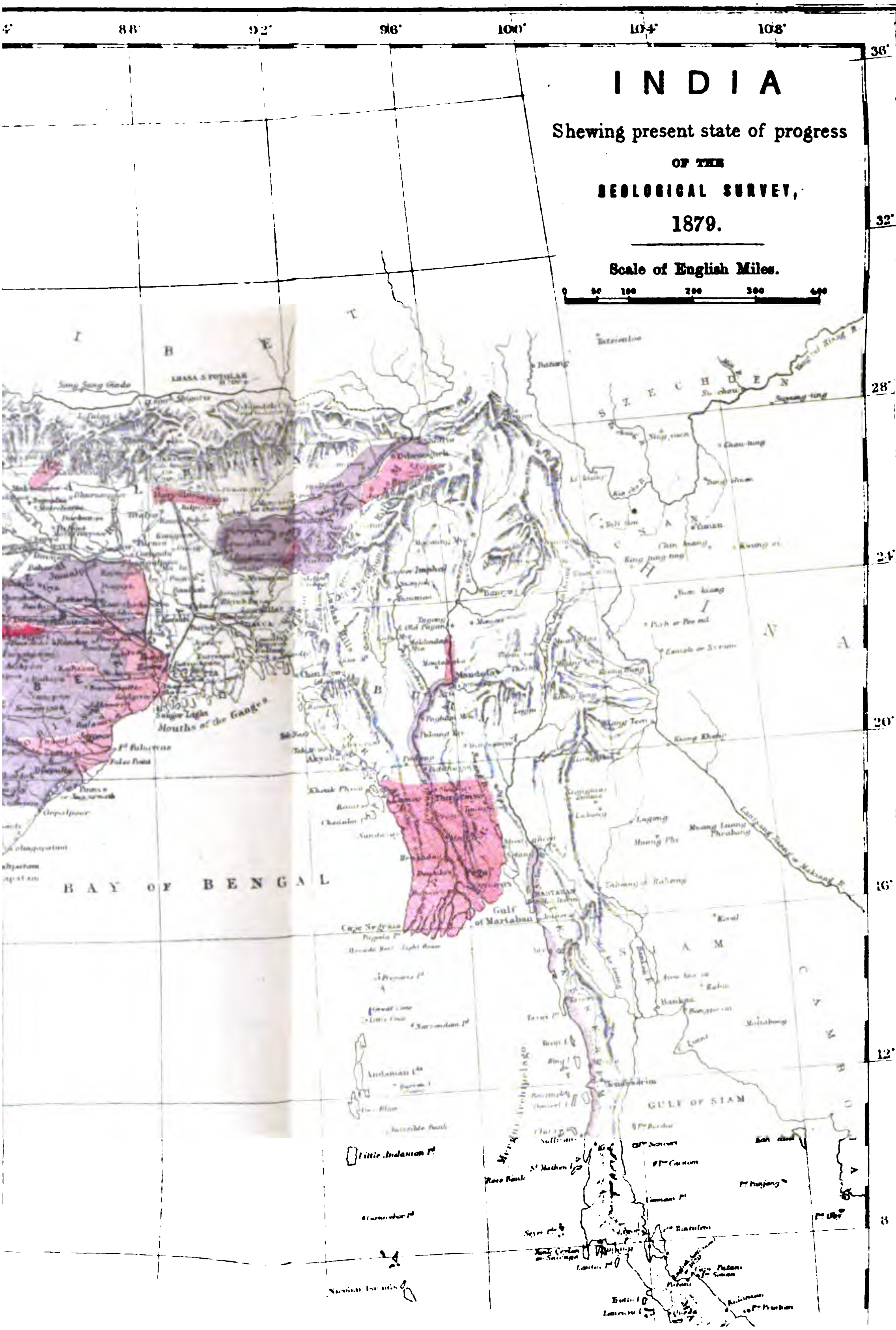

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GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1879. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1878.

In the report for a year that has been comparatively unproductive of fresh work, I have to record, as compensation, the completion of the Manual of the Geology of India. The two facts are, indeed, closely connected: The Manual is principally—readers will often find cause to regret that it is not all—the work of Mr. Blanford, who was thereby prevented from taking the field in the open season of 1877-78. When results are to be measured by the knowledge gained from the study of obscure facts, many circumstances affect the tale of progress, which depends more upon the study than upon the accumulation of what are called observations. Geology has suffered much from the delusion that the two offices can be separated.

The Manual itself is a progress report *in extenso*—a full summary both of what is known and of what we fancy to be known regarding the geology of India, *i.e.*; of supposed (partial) facts, and of the apparent conclusions therefrom. Despite explanation and cautions given, students are likely to forget the very scanty and crude state of the information upon which much of the work is based, and therefore how liable to overthrow are the inferences suggested from that information. Such inferences have been freely offered in the Manual, in order to give point to the description, and to incite other observers with the agreeable encouragement of discovering error. Now that a more intelligent understanding is gaining ground regarding scientific method, the rational use of hypothesis as opposed to dogma, it is possible to be instructive without misleading others or stultifying one's self. Unfortunately, our work in India still suffers from the impunity with which either blunder might be committed; as the business of correction and exposure is almost entirely in our own hands. The duty of self-correction will not, however, be lost sight of, or evaded. The Manual affords an excellent datum-line, available to all, from which to mark the phases of our

progress, and the annual report is the appropriate medium for bringing to notice such changes as have become necessary in the provisional interpretations of that date. Already, almost cotemporaneously with the publication of the Manual, the balance of evidence on some points has been affected by the results of the last season's work, as will be mentioned in the following remarks.

Before alluding to this work of detail, I would make mention of some general observations on the geology of India published within the year, and based upon the work of the Survey. Our distinguished colleague, Dr. Waagen, whose services, I am happy to say, are still engaged in our behalf, so far as his health will permit, presented to the Academy of Vienna a sketch of the geology of India based upon a discussion of its palæontology. Work of this kind is of the highest value and interest, as representing the results and the rationale of the details of palæontological research. For the benefit of English students, in India or elsewhere, a translation of the paper is published in the Records for November.

So far as relates immediately to India, the features evolved are of permanent importance. The only misgiving that occurs to one in respect of the wider generalizations is, that the provisional condition of the biological principles upon which most of these deductions depend may not have been sufficiently kept in view. Several relations in the comparative palæogeography of very distant countries are confidently assigned, on the assumption of certain laws of distribution of life, in time and space. Now, however confident we may feel regarding the general principle of the derivation of organic forms, the particular view of that principle necessary to the validity of such speculations as those under notice is still under discussion, and the familiar application of it, as if established, may (or even must) seriously interfere with the verification and study of the great biological problem which is the highest object of geological pursuit, and as subsidiary to which these geographical puzzles are principally of any interest. To those who are awake to the importance of the vital question, even though they may not be qualified to discuss it directly, such interference is a subject of regret.

In the last presidential address to the Geological Society of London, Professor Martin Duncan gives a most instructive review of many complicated problems in zoology and palæontology. From his statement of the objections to accepting the relative classification of the tertiary rocks of India, as recently put forward by the Survey, it might be thought that some decidedly unscientific prejudice had had influence in the discussion. Objections are of more service to us than approval, and some of those made by this high authority may not be so easily removed as the one I have mentioned. With the greatest respect for the work of the illustrious Falconer, of whom we are most justly proud as the local founder of palæontological research, it was not thought that his views could be final, or that they were compatible with a fuller knowledge of the formations. He had treated as one fauna the fossils from a prodigious series of strata, in which those fossils are by no means promiscuously distributed. It did not seem even that Falconer himself had considered his opinion conclusive on these points of correlation, more especially as regards the older gravels of the Indian river valleys.

When, therefore, a stone implement was found in these gravels, it was made the occasion of a special consideration of some features of the case that had not previously been discussed. This proceeding was no more than was demanded by the peculiar interest of the occasion. The same judicious caution has markedly characterized the most recent investigations by perfectly impartial observers regarding the human period in England.

Peninsular area: Azoic rocks.—To follow the order observed in the Manual, the azoic rocks are noticed first. The Arvali region is the only ground where we have been especially engaged upon these formations during the past season. Mr. Hacket examined a very large area at the northern extremity of the range, with all the outliers between Deeg and Toshám (near Hánsi), up to the Jumna at Delhi. Mr. Hacket has hitherto had this area all to himself, and at pages 48 to 52 of the Manual an abstract is given of the provisional views then suggested. Very considerable changes in the stratigraphical series are now proposed. The Mandan and Ajabgarh groups, lying mainly to the west of the Alwar and Delhi range of quartzites, were placed at the top of the series. The Mandan rocks occur in isolated ridges, and were separated from the Ajabgarh beds on account of the absence of certain bands that are prominent in the latter group; while the Ajabgarh beds were placed above the Alwar quartzites on account of some cases of steep, partial superposition which must now be regarded as inversions, for Mr. Hacket considers both the Mandan and Ajabgarh beds to be representative of the Raiálo group, underlying the Alwar quartzites. In the study of extensive areas of contorted transition rocks, the tendency is usually towards a greater subdivision and expansion of the series, original features of unconformity being often disguised by the crushing of the strata; but Mr. Hacket makes out a good case for this contraction of the Arvali series, as first proposed. The very mixed and variable character of the deposits of the Raiálo group was pointed out from the first; and in this as well as in other petrological characters the agreement of the Mandan and Ajabgarh rocks is sufficiently close, besides that new sections have shown these to have the same relation as the Raiálos to the gneiss and to the Alwar quartzites.

The adoption of two instead of four groups is, so far, an apparent simplification; but the chief structural difficulties of the ground are still unexplained. These are, the almost incompatible variations in the relations of these groups to each other and to the gneiss. In many sections the two groups are described as completely transitional, by interstratification. Again, each group is locally described as transitional with the gneiss: the Raiálo black slates passing down into a dark schistose gneiss; and the Alwar quartzites being transitional downwards with a gneiss that is only a subfoliated felspathic quartzite. But in other sections the Alwar quartzite is described as overlapping on gneiss, as in the hills between Udepur and Khandela, 40 miles north-west of Jeypore. These discrepancies might be got over by assuming that all the gneiss is simply converted Arvali strata, the metamorphism having extended locally to different horizons; and that the word 'overlap' is misapplied in such cases, for it implies a primitive gneiss, with original local absence of the Raiálo group; and no distinction of gneisses has been

attempted. This easy solution of the difficulty might be adopted, were it not that other observations independently require such original conditions as are implied by overlap: in the little hills south of the railway between the Basi and Jatwára stations, 20 miles east of Jeypore, a coarse conglomerate occurs at the junction of the Alwar and Raiálo groups, containing large boulders of gneiss, quartzite, limestone, and of a banded jaspideous rock, in a schistose matrix. Now, it seems impossible, under any recognized doctrines of rock-formation, to consider such debris as this to be derived from the series in which it occurs; and the gneiss boulders especially require the supposition of a metamorphic series older than that of the Arvalis themselves, and upon which an overlap of the Alwar quartzites might naturally occur. But no such rocks have been discriminated within the very large area of these formations explored. Should this stratigraphical evidence fail, it may be permissible to suggest some primitive conditions of rock-formation, involving some very rapid process of induration of deposits, or even their crystallization, to take the place of what is commonly implied by metamorphism; and also involving much greater facilities of very local disturbance, whereby the same deposits may be strongly unconformable and in unbroken sequence, within close proximity. The proved extreme antiquity of the transition rocks of the Indian Peninsula admits, perhaps, of some appeal to conditions differing widely from any standard of processes now in operation. These rocks may, indeed, be azoic in the original acceptation of the term—anterior to the appearance of life in this portion of the earth's surface.

The foregoing remarks refer only to the Arvali rocks, as hitherto described; but Mr. Hacket's observations of last season lead him to extend these views to some rocks of the adjoining region to the east, although without a re-examination of these sections. The change offers an immediate relief from the difficulties stated on pages 51 and 52 of the Manual. At the eastern edge of the Arvali region, close along the scarp of the Vindhyan series, there appear in the Hindaun ridge some typical representatives of the Gwalior series. In their standard area, to the east of the Vindhyan basin, these rocks rest, undisturbed and completely unconformable, upon the gneiss of Bundelkhand; and the puzzle was to find a place for these Gwaliors of the Hindaun ridge, either between the Vindhyans and the Arvali series, or between these and the Arvali gneiss; the former alternative being provisionally accepted as the least anomalous. It was thought that the peculiar composition of the Gwalior rocks and their local unconformity to the Arvali series forbade their being identified with this series. Now, however, Mr. Hacket considers that, as with the Mandan and Ajabgarh groups, so the Gwalior rocks must be brought within the horizon of the Raiálo group, and for similar reasons. The most peculiar and prevailing character of the Gwalior series is the presence of jaspideous bands, generally of a bright red colour. The very special nature of this rock, however abundant locally, would be in itself an excuse for not insisting upon it as a character of wide extension. The objection is, moreover, modified by the occurrence of compact silicious bands in the Raiálo group, as in the hills near Sathána in Shaikhawáti; near Chenpura, north-east of Basi railway station; and near Muhammadpur, south of Kherli station.

The Gwalior rocks have been independently ranked as in the upper transition series of Peninsular India, as probably equivalent to the Kadapah series of Southern India; and thus the Arvali series, in great part metamorphic, would be brought into a more defined position in the general scale of Indian formations.

Gondwána rocks: Palamow.—On page 198 of the Manual mere mention could be made of the 'unsurveyed basins of Palamow.' A description of these coal-fields by Mr. Ball, with maps, has since been published (Mem. G. S. I., Vol. XV, pt. 1). This ground is more accessible from the trunk railway than the coal-basins of the upper Damuda valley; and projects for working the coal have lately been proposed. Two new coal-fields have been marked in the basin of the Koel river: the Aurunga field on the east has an area of 97 square miles; and the Hutár field on the west, traversed by the river Koel, has an area of 78 square miles. Both measurements include the whole of the Gondwána deposits, but the areas to be deducted from the Talchir outcrop are small. So far as could be determined from surface indications, the coal of these areas, especially in the Aurunga field, is not so good as that of the smaller Daltonganj field, lower down the Koel, to the north.

The geological interest of this ground is, that here a marked change takes place in the petrological characters of the Gondwána system, between the series as developed in the Damuda valley coal-fields and that found in the great midland area of South Rewah (the Son region), as well as in the Mahánadi and Godávari regions. In the Damuda region three considerable deposits (the Ironstone Shales, Ránigaņj, and Panchet groups), of lower Gondwána age, are petrologically well distinguished from the lower coal-measures (Barákar group). These groups are here overlaid by a thick sandstone, generally characterized by its comparative want of earthy bond, and its consequent porosity. It was originally named the upper Panchet group, in the Ránigaņj field; but from its presumable equivalence to the Dubrájpur sandstone of the Rájmahál region, in which upper Gondwána fossils occur, and from partial unconformity, it has latterly been separated from the lower Gondwána series, under the general name 'Mahádeva,' which is at present a partial equivalent for upper Gondwána. In the midland and south-eastern regions a sandstone of this type rests immediately upon beds representing the lower coal-measures of Bengal, and overlap-unconformity is at many places very marked at this horizon. Notwithstanding these marks of changed conditions, it appears from the fossils that a great thickness of these upper sandstones (Kámthis) in the Godávari valley must be recognized as lower Gondwánas, possibly on the horizon of the Ránigaņj group of the Damuda fields.

Mr. Ball established the same fact for the upper sandstones at Hengir in the Mahánadi region; and he now (*l. c.*, p. 46) confirms the observation of the strong resemblance between that rock and the sandstone resting on the lower coal-measures in Western Palamow, but which he shows to be unquestionably identical stratigraphically with the supra-Panchet sandstone of the Damuda area. Upon this the suggestion is made that the Hengir rocks present a blending of the characteristics of two groups, which in Palamow are separated by a distinct

interval. Of such distinct interval, however, no more direct stratigraphical evidence is found in Palamow than elsewhere, beyond the original fact of the intercalation of deposits not found away from the Damuda area: the apparent sequence of the upper sandstone (Maháderas of Mr. Ball's report) on the Barákars here being at least as regular as in the south-eastern Gondwána regions; so that the expectation to find lower Gondwána fossils in this rock here would still be justified. Thus, the question stands pretty much as before, save that we know exactly where this change of petrological characters takes place.

It had been surmised that this change would coincide with the limits of the Damuda valley; but Mr. Ball has found that it is not so. A barrier of gneiss, between the Kárunpura and Aurunga coal-basins, divides the waters of the Damuda and the Aurunga, which is a tributary of the Koel; and in the eastern part of the Aurunga field the Panchet and Ràniganj groups are about as well developed as in the Kárunpura field, their combined thickness being about 1,700 feet, and they are covered by the upper sandstone. Notwithstanding this great development in thickness, the extension of these two lower Gondwána groups is strangely limited. The feature under notice is, indeed, brought within a compass of two miles in the hills south of Latehár, at the west end of which the upper (Mahádeva) sandstone rests on Barákars, and at the east end on Panchets. Both the north and south boundaries are represented as faulted, so that the overlap cannot be followed out; but this case gives at least the assurance that the covering sandstone, so differently circumstanced at its base, is one and the same formation. The absence of fossils in these sections is deplorable. Without them the position of this top sandstone in the general series must remain doubtful: in the west of the Aurunga field its relation to the coal-measures is precisely like that of the Kámthi and Hengir rocks to the similar coal-measures of the Godávari and Mahánadi regions, while in the eastern part of the field it overlies beds (Panchets), which in turn overlie those (Ràniganj) that have been correlated with the Kámthis.

The gneissic barrier between the Aurunga and Kárunpura fields being much higher relatively to the former than to the latter, Mr. Ball considers that the separation is due to disturbance, by a sinking of the Aurunga basin; so that they may still be virtually considered as belonging to the same original area, and the similarity of the sections be attributed to some peculiar conditions of that ground.

In the Son region, shortly to the west of Palamow, the upper sandstone series becomes enormously expanded; and if, as seems probable, this rock in Palamow represents the base of that expanded series, which, again, in its southern extension is likely to be identified with the Kámthi beds of Hengir, then the top sandstone of the Damuda region cannot properly be classed as upper Gondwána (Mahádeva), or identified with the Dubrájpur group of the Rájmahál region; nor could the Kámthis then be properly correlated with the Ràniganj group, unless a certain correspondence of the fossil floras at distant localities is to set aside local superposition in the Damuda region, represented elsewhere by the most clearly and most widely marked stratigraphical change in the whole Gondwána series.

It is independently a most puzzling circumstance, how such great overlap, as that described within the sedimentary series in the Aurunga basin, can be attended by so little evidence of unconformity in adjoining ground. Mr. Ball's supposition that much disturbance and denudation, whereby the chain of coal-basins of the Damuda valley were defined, and whereby the deposition of the upper sandstone was limited to that depression, intervened before the deposition of the upper sandstone, almost increases the difficulties of the case in the absence of any evidence for such unconformity as must have attended that event.

The most distinct case of apparent disturbance-unconformity observed by Mr. Ball (*l. c.*, p. 87) is between the upper sandstone and the Panchets, not between it and the lower coal-measures. It is still an open question whether the apparent anomalies of these sections may not be largely traced to original (pre-Gondwána) conditions of the surface.

Godávari region.—From the foregoing remarks it will be understood that the distinction of upper and lower Gondwána rocks in the Damuda region is still presumptive, based principally on the supposed equivalence of the top sandstone of the series with the undoubted upper Gondwána sandstone of the detached area to the north-east, in the Rájmahál hills, and upon occasional cases of overlap-unconformity in the Damuda coal-fields. But similar unconformity and great irregularity occurs also in the upper groups of the recognized lower Gondwánas of the Damuda region; while the most marked lithological change and overlap-unconformity in the midland and southern Gondwána regions is found within the lower Gondwána series, between the coal-measures and the Kámthi-Hengir sandstones, which in this direction present the most marked analogue of the top sandstone of Palamow.

In the Godávari region the fixing of this middle Gondwána horizon has been for some time, and is still, a great puzzle. On the lower Godávari it seemed to be made out by Mr. King, between the local representatives of the Kámthi group and the Golapilli sandstones, containing a Rájmahál flora; and Mr. King thought he identified this group on the Pránhita, just above its confluence with the Godávari, in the sandstone of Sironcha, having found Golapilli fossils in what he took to be a top band of this sandstone at Anáram, near Kota, not far below the well known *Lepidotus* limestone of that place (Rec. G. S. I., Vol. X, p. 55).

Working from the north, Mr. Hughes found no upper Gondwána rocks in the Wardha coal-basin, but at the southern edge of that area, on the lower Wardha, about Porsa, the Kámthis are overlaid by red clays, which are identified with the well known *Ceratodus* clays of Maleri. This formation spreads rapidly to the south. It is locally covered on the east by the plateau-forming conglomeratic sandstones of Chikiála, resting against Vindhyan rocks; and to the west it extends far up the Jangaon valley, gradually overlapping the Kámthi strata, so as to rest against Vindhyans, and then passes under the Deccan trap. Here, too, plant fossils of decided upper Gondwána type were found, so that on this cross-section the whole Gondwána area, 50 miles wide, is occupied by well

marked upper Gondwána strata. South of the Jangaon valley the Kámthis emerge again in force, encroaching upon the upper rocks up to Sironcha, where the latter are reduced to a width of six miles. Mr. Hughes carried his lines up to the Godávari and the Pránhita at Sironcha, recognizing no group between the Kota-Maleris and the Kámthis. Here he encountered Mr. King's Sironcha sandstone, the lithological peculiarities of which he admits, considering it more like the rocks associated with the Maleri clays, than it is like the typical Kámthis (Rec. G. S. I., Vol. XI, p. 23). If, however, this rock, as mapped by Mr. King up to the Godávari from the south, is to be taken in this light, or as a group distinct from both Maleris and Kámthis, or, as would appear on Mr. Hughes' map, in great part as a peculiar form of the upper Kámthis, a part of the ground mapped north of the Godávari will have to be modified accordingly.

Mr. King's observations of last season are still conflicting as to which of these views may prove true. He finds the conglomeratic sandstone of Anáram, with which the upper Gondwána fossils occur, to be local, and considers it more likely to be a local deposit, or a remnant of an overlying formation, than to belong to the underlying Sironcha sandstone. Again, he describes regular Sironcha sandstone as unconformably overlaid by the reptilian clays of the Agrezpali outlier, on the Godávari, 16 miles above Sironcha. Mr. Hughes thought these clays might be high in the Kota-Maleri group; but Mr. King does not adopt this suggestion, and considers them on the horizon of the beds at Maleri. Thus, these two observations are strongly suggestive of the Sironcha being lower Gondwána, either as upper Kámthis, or as an independent group.

On the other hand, Mr. King is in favour of a division of the Kota-Maleri group, as he finds that its upper portion only, at and above the horizon of the Kota limestone, is represented in the prolongation of that formation south-east of the Pránhita, overlying, if not faulted against, the Sironcha sandstone. Such an overlap would be valid ground for reviving the original question of the probably marked separation of the *Lepidotus* limestone and the *Ceratodus* clays. In this connexion Mr. Hughes' partial identification of the Sironcha sandstone with that associated with the Maleri clay (Rec. G. S. I., Vol. XI, p. 23) is suggestive of the possibility that these two rocks are locally representatives of each other. In this case the views given in the preceding paragraph would require modification: the search for the middle Gondwána horizon would have to be taken up again, even in the Kota-Maleri area; involving the reinvestigation of the horizon of the plant beds in the Jangaon valley, as to whether they may not be in the upper division of the group, as is indeed suggested by the probable identification of the Chikiála beds at Balánpur. Mr. King hopes to be able to revise, and decide upon, these crucial points during the present season.

Early in the season Dr. Feistmantel visited the Sátpura coal-basin, to examine on the ground some good sections of the Gondwána series, the flora of which he has been studying and describing so carefully, and with great advantage to the Survey. The coal-measures of those fields were always taken to represent Barákars, the lowest of the Damuda coal-measures; and Dr. Feistmantel has shown

that they belong rather to that still lower horizon of coal-bearing strata, represented by the Karharbári measures in Bengal.

On the western confines of the Peninsula, where the Gondwánas become associated with marine strata, Mr. Fedden broke new ground in Kattywar. He was detained by office work in Calcutta, in classifying some of the collections made by him in previous years, and arranging them in the new Museum, and he consequently did not take the field till the end of 1877. In the early months of the past year he surveyed a portion of Kattywar, amounting to about 1,800 square miles, comprised in Topographical Survey sheets 21, 22, 23, and portions of some of those adjoining. Mr. Fedden speaks very highly of the excellence of these maps. The country examined is for the most part flat, and the rocks consist of Deccan traps, overlying sandstone, in which some remains of plants were found. These plants prove to be identical with those occurring in the uppermost jurassic or Umia beds of Cutch, and it is thus clear that a portion at least of the Cutch jurassic series extends into Northern Kattywar.

The greater part of the area examined consists of jurassic sandstone, the hills being of trap; but to the southward, where the surface is more hilly, the traps cover the country. The beds, both of sandstone and trap, are nearly horizontal. In some places between the jurassic beds and the traps a thin band of limestone is found, which contains a few obscure marine organisms. This band may perhaps represent the Bágh beds of the Narbada valley. A few intertrappean bands are found, and some outlying patches of milliolite were noticed resting on the trap.

In Southern India Mr. Foote took up new ground to the south of Trichinopoly. In crossing the cretaceous area he made some valuable additions to our fossil collections from those formations. He also re-examined the localities where the Utatúr plant beds occur at the base of the series. He completely identifies them with the jurassic beds containing both plants and marine animal remains, described by himself, at many points along the coastal region up to the Kistna. From the entire similarity of the fossil plants and their mode of preservation to those of the deposits elsewhere in which marine fossils are described in the same beds, Mr. Foote is of opinion that the Utatúr plant beds also are probably marine; in support of which view he mentions his inability to find stratigraphical evidence (more than overlap) of a break between them and the overlying middle cretaceous deposits, thus confirming the previous observation of others upon this interesting point. Mr. Foote's notes upon these features are published in the Records for the year.

The country south of Tanjore has, so far, proved very uninteresting; no rock appearing between the gneiss and the coast alluvium, except the Cuddalore sandstone formation, intimately blended with the covering laterite.

Extra Peninsular area.—In the extreme North-Western Punjab, Mr. Wynne made a preliminary examination of some new ground in Hazára, having been prevented by difficulties on the frontier from following the formations of the Salt Range across the Indus into Bannu, as had been proposed. Owing to the exceptionally wet season, and illness occasioned thereby, the amount and details of the

work are not what Mr. Wynne expected to accomplish; still he has given a most useful reconnoissance of the ground: the limits of the crystalline rocks forming the higher mountains have been defined, and a tentative classification and distribution given of the unaltered sedimentary series to the south of the gneissic area.

The most interesting feature of the observations is the extension to the older rock-series of the contrast which has been known to exist in the newer formations, between the Southern Himalayan area and the country to the west of the Jhelam. In Huzára the rocks adjoining, and apparently in sequence with, the gneissic rocks are a great thickness of sandstones, quartzites, and dolomites, called by Mr. Wynne the 'Tanól series,' presenting little or no correspondence with the strata similarly related to the gneiss of the Pír Panjál. But the most anomalous circumstance is, that Mr. Wynne provisionally identifies the Tanól series with the 'Infra Trias' group of the section in Sirban mountain (west of Abbottabad), which is there distinctly in unconformable superposition on the Attock slates (*see* Manual, p. 499), this relation not being so clearly defined at the junction of these slates with the main area of Tanóls, west of Abbottabad. If these conjectures are confirmed, it would seem that the gneiss of Hazára is much newer than the central gneiss of the Himalayas.

The severe famine in Kashmir interfered much with Mr. Lydekker's work in the North-West Himalayas. This, and a temporary indisposition, prevented his carrying out his projected trip to the Gilgit region; so he spent the season in the mountains of Drás and Tilail, where he has described some important sections of the sedimentary rocks. Mr. Lydekker insists strongly upon the transitional relations of the whole series from silurian to upper triassic (*see* Manual, p. 660).

Colonel McMahon has again made an important contribution to our work in the Himalayan regions—this time in the Central Himalayan districts, to the north of the Simla region of the lower Himalayas. His observations involve a reconsideration of some views provisionally put forward in the Manual, while yielding confirmatory evidence upon others.

The strongly unconformable relation of the limestone and slate series of the lower Himalayas to the central gneiss, presented some difficulty as compared with the pseudo-conformity of the same sedimentary series to this gneiss on the Tibetan side (Manual, p. 679 (*a*)). Colonel McMahon describes this northern junction within four miles of the intrusive granitic mass of Gongra, between Lipe and the Ruhang Pass, as exhibiting an appearance of transitional metamorphism, which contrasts with the more abrupt contact at the Bhabeh Pass and in Niti. Such local action does not, however, disturb the inferences based upon the other sections. On the other hand, he observed in Hangrang, east of the lower Spiti valley, the upper (Muth) beds of the slate series to be in original superposition on gneiss at the base of the Purguil Mountain, the gneiss being, up to the very contact, profusely cut up by large and small granite veins that do not penetrate the overlying limestone and slates, which are not described as more altered than at points remote from the crystalline rock. This would appear to fix a very definite limit as to the age of these granitic veins; and the total overlap of the

great mass of the slate series establishes for this area original conditions of unconformity with the central gneiss, like those already exhibited in the Simla region. The position of this overlap, against the transverse gneissic mass of Purgul, shows, moreover, that this barrier between the Zánskár and Hundes basins is of very old standing, though it may not always (since palæozoic times) have been so prominent as now.

Another important observation of Colonel McMahon's is his reaffirmation of Stoliczka's original identification of the Krol limestone with the Lilang limestone of Spiti. This decided opinion, based upon immediate comparisons of the sections in those adjoining regions, although separated by the great gneissic axis, cannot be set aside; it is at least as valid as the very broken chain of evidence upon which a different correlation was provisionally adopted in the Manual (pp. 595-6). The intimate connexion of the triassic and carboniferous series, as urged by Mr. Lydekker, will, in the absence of fossils, make the close decision of this question a matter of greater difficulty.

Mr. Theobald made large additions during last season to our collections of the Siwalik fauna, the results of which are duly recorded, up to date, in Mr. Lydekker's papers in the Records and the Palæontologia Indica. Mr. Theobald is now engaged upon the tertiary zone east of the Ganges in Rohilkhand, at the base of the Himalayas of Garhwál and Kumaun.

Mr. Mallet was deputed in December to report upon some coal seams in Rámri Island, reported by the Commissioner of Akyab. Mr. Mallet could not form a favourable opinion of the practical value of these measures; the coal is inferior to that of Bengal, and the measures are greatly disturbed, and would be very difficult to work. Specimens of a very different coal, a bright jetty lignite, were forwarded by the Commissioner from the Baránga Islands. The site of this coal has not yet been discovered; but the fact that the piece sent is distinctly a piece of carbonized wood, suggests the probability that it occurs in isolated logs, and not as a continuous seam. The petroleum of this region seems, so far, to offer more favourable prospects than the coal.

My own time was fully engaged throughout the greater part of the year in directing the work of the Survey, and in editing the publications, including the Manual. Without a fully qualified Assistant permanently at head-quarters to relieve me of some of these very important and responsible duties, it is most difficult for me to undertake effectively the more congenial occupation of examining crucial questions in the field. The cumbersome arrangements for camp life, and the slowness of moving about in this way, prevent any compensating results being obtained within much less time than a full season in the field. At the same time I feel that my long experience in field work is not used for the best advantage of the Survey unless as partially applied in that way.

In February I made a short trip to the North-West Provinces, to serve on the Committee appointed for investigating into the causes of deterioration of land by *reh* in the Aligarh district. I had many years ago made some partial observations on this subject; and I have been again strongly impressed with the

extensive injury to cultivation to be apprehended from reh in connexion with canal irrigation in the excessive climate of North-Western India. My notes on the subject were submitted to the Committee, and published in its report.

I took the opportunity while in the neighbourhood to investigate two recent cases of supposed discovery of coal: one in the Siwaliks of Dehra, reported by the Railway Department, and one in the same rocks of Náhan, to which my attention had been called by the Punjab Government. From my pretty accurate acquaintance with this ground, I was fully satisfied that the reports were fallacious; but in regard to the importance of the subject, and to the general want of confidence in independent geological judgment, I visited both localities. The result was what I expected: it would have been impossible to extract one hundred-weight of coal from all that was left of the supposed "seams." The repeated revival of these oft exploded discoveries is one of the chronic evils of the perpetual change of staff in every office throughout India.

Publications.—Two principal Memoirs, expected to be issued within the year, have been unavoidably kept back. As explained in last year's report, the letter press and plates of Mr. Wynne's report on the Salt Range, forming Vol. XIV of the Memoirs, were then ready for issue, waiting for the colour-printing of the map. This has not yet been received. Fully coloured proofs have recently been passed for press, and the issue of the report cannot now be much delayed. The postponement of Mr. Blanford's Memoir on Sind has been already explained. Mr. Foote's Memoir on the Nellore District is in hand for publication. Thus the only number of the Memoirs actually issued during the year was Part 1 of Vol. XV, containing Mr. Ball's report (with three maps) on the Palamow coal-fields, of which a notice has already been given. By orders of Government, the price of these volumes has been considerably reduced.

THE RECORDS for 1878 are, by way of compensation, much more full of matter than usual, extending to three times the size originally contemplated, and containing numerous outline-maps.

Of the PALÆONTOLOGIA INDICA two large parts were issued during the year: one by Dr. Feistmantel on the flora of the Jabalpur group, containing 14 plates, and one by Mr. Lydekker on the crania of fossil Ruminants, containing 18 plates. Two other parts by the same authors are now in the press. A revision of the somewhat confused classification of these publications has been made, for publication on the covers, from this date. The price has also been reduced.

Museum.—So far as compatible with other current work, good progress has been made in the arrangement and labelling of the collections in the new cases by Dr. Feistmantel and Mr. Lydekker in the palæontological galleries, and by Mr. Mallet in the mineral gallery. The frequent calls on Mr. Mallet for occasional assays and analyses, form a serious but unavoidable interruption to the systematic examination he is making of the mineral products of India, so far as represented in our collections.

Library.—During the past year 950 volumes, or parts of volumes, have been added to the library: 462 by purchase, and 488 by presentation or in

exchange. The new fittings in the library were completed within the year, so it will now be possible to complete the thorough arrangement of the books.

Personnel.—Mr. Hughes was absent on furlough for the whole year. Mr. Ball left on two years' furlough on the 1st of July. Mr. Lydekker was absent on privilege leave from 9th February to 8th of May; Dr. Feistmantel, from 21st of March to 20th of June; Mr. Mallet, from 2nd July to 19th of October; and Mr. King, from 27th July to 21st October.

I regret to have to record the death, on the 23rd March, of Mr. Walter Lindsay Willson, who joined the service in March 1857. He had then been for some years senior geologist on the Geological Survey of Ireland; and the training he had there received was very marked in the finished neatness of his field-maps in India.

Mr. Carl Ludolf Griesbach, F.G.S., was appointed by the Secretary of State in the room of Mr. Willson, and joined his post on the 11th November. Mr. Griesbach's acquaintance with the Karoo formation of South Africa will be of service in elucidating the supposed correspondence of those strata with the Gondwána series of India. He has accordingly been deputed to take up work for the present on these rocks in the Sone region, in continuation of Mr. Ball's survey of Palamow.

Apprentice Kishen Singh was on duty till November with Mr. Theobald, who reports favourably of his intelligence, zeal, and good conduct. Apprentice Hira Lal was on duty at head-quarters, where he performed useful service in the Museum under Mr. Mallet and Dr. Feistmantel. He was sent to the field with Mr. Griesbach in November, when Kishen Singh was recalled to take up the duties in the Museum.

H. B. MEDLICOTT,
Supdt. of the Geological Survey of India.

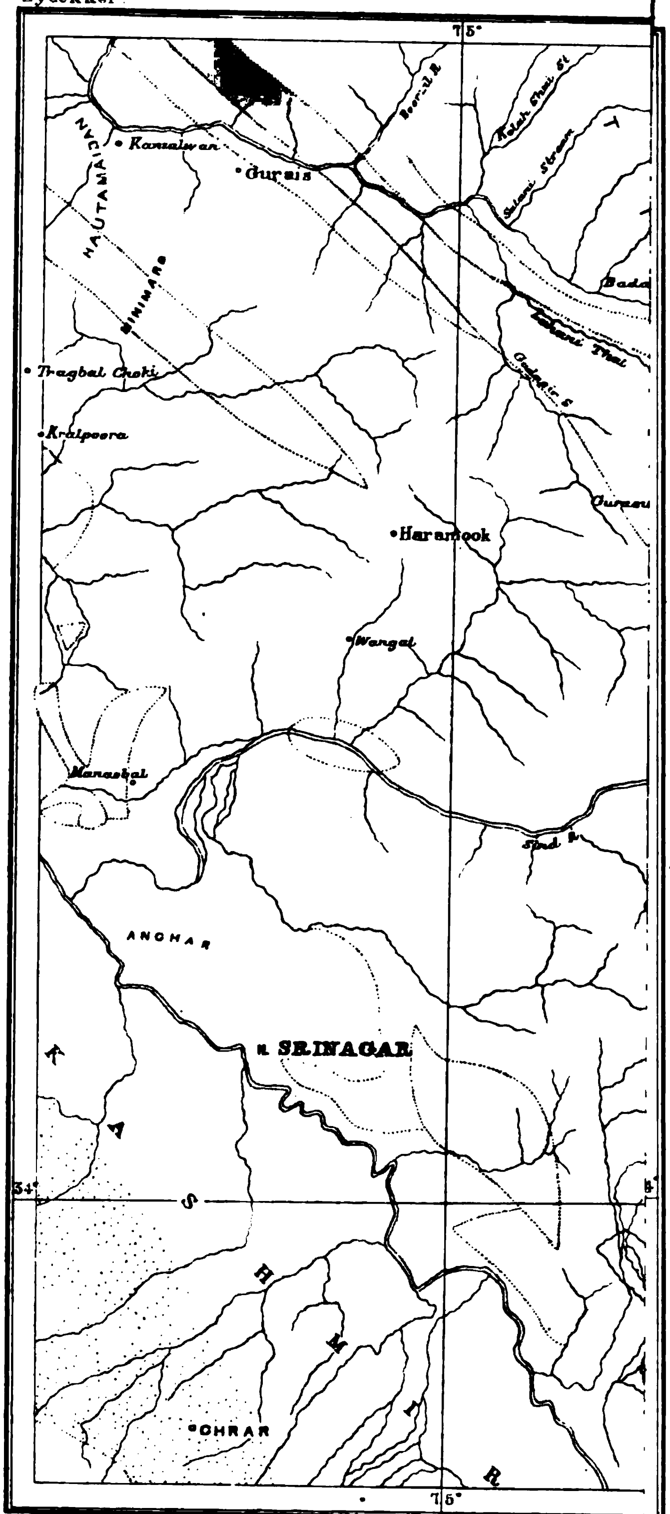
CALCUTTA,
January 1879.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1878.

AMSTERDAM.—Royal Society of Batavia.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
 „ Royal Prussian Academy of Sciences.
BOMBAY.—Bombay Branch Royal Asiatic Society.
BOSTON.—American Academy of Arts and Sciences.
 „ Boston Society of Natural History.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Bristol Museum.
 „ Naturalists' Society.

BRUSSELS.—Geological Society of Belgium.
„ Belgium Geographical Society.
BUDAPEST.—National Museum.
CALCUTTA.—Asiatic Society of Bengal.
„ Agricultural and Horticultural Society.
„ Meteorological Survey.
CAMBRIDGE (MASS).—Museum of Comparative Zoology.
CAPE TOWN.—Department of Crown Lands.
CINCINNATI.—Zoological Society.
COPENHAGEN.—Royal Danish Academy.
DAVENPORT.—Academy of Natural Sciences.
DIJON.—Academy of Sciences.
DRESDEN.—The Isis Society.
„ Kais. Leopol.-Carol. Deuts. Akademie.
DUBLIN.—Royal Geological Society of Ireland.
EDINBURGH.—Royal Society.
GENEVA.— Physical and Natural History Society.
GLASGOW.—Glasgow University.
GÖTTINGEN.—The Göttingen Society.
LAUSANNE.—Vaudois Society of Natural Science.
LIVERPOOL.—Geological Society of Liverpool.
„ Literary and Philosophical Society.
LONDON.—British Museum.
„ Geological Society of London.
„ Linnean Society of London.
„ Royal Geological Society of London.
„ Royal Institution of Great Britain.
„ Royal Society of London.
„ Zoological Society of London.
MADRID.—Geographical Society of Madrid.
MELBOURNE.—Mining Department, Victoria.
„ Royal Society of Victoria.
„ Geological Survey of Victoria.
MINNESOTA.—Geological Survey of Minnesota.
„ Academy of Natural Sciences.
MOSCOW.—Imperial Society of Naturalists.
MÜNICH.—Royal Bavarian Academy of Sciences.
NEW HAVEN.—Editors of the American Journal of Science.
PARIS.—Geological Society of France.
„ Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Society of Natural Science, Tuscany.

Lydekker.



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GEOLOGICAL OUTLINE OF

PLYMOUTH.—Devonshire Association.
ROME.—Geological Commission of Italy.
" Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SALEM. MASS.—American Association for the Advancement of Science.
" Essex Institute.
STOCKHOLM.—Royal Academy of Science.
ST. PETERSBURG.—Imperial Academy of Sciences.
SYDNEY.—Royal Society of New South Wales.
TASMANIA.—Royal Society.
TURIN.—Royal Academy of Sciences.
VIENNA.—Imperial Academy of Sciences.
" Imperial Geological Institute.
WASHINGTON.—Department of Agriculture, U. S. A.
" Smithsonian Institute.
" U. S. Geological Exploration of the 40th Parallel.
" U. S. Geological and Geographical Survey.
WELLINGTON.—Geological Survey of New Zealand.
" New Zealand Institute.
YOKOHAMA.—German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.

Governments of Madras, Bengal, and the Punjab; Chief Commissioners of Central Provinces and Mysore; Superintendents of Great Trigonometrical and Marine Surveys; Foreign, Home, and Revenue, Agriculture and Commerce Departments.

GEOLOGY OF KASHMÍR (*3rd notice*), *by* R. LYDEKKER, B.A., *Geological Survey of India.*

With a Map.

INTRODUCTION.

Partly owing to the famine-stricken condition of the country, and partly owing to personal disabilities, my geological work during the past summer in the Kashmír Himalaya has been of but very limited extent, and only a comparatively small area of country has in consequence been surveyed. The work which I have accomplished is noticed in the present paper which treats chiefly of the geology of the Tilail and Drás districts, and also of a few places in the valley of Kashmír which had not been previously surveyed. This paper must be read in conjunction with my two previous papers on Himalayan geology, entitled "Geology of the Pír Panjál," and "Geology of Kashmír, Kishtwár, and Pangi."[1] I shall frequently refer to the latter as "my last paper."

[1] Rec. Geol. Surv. India, Vol. IX, p. 155, XI, p. 30.

I.—VALLEY OF THE JHELAM AND KASHMÍR.

I have first to correct the map published in the "Geology of the Pír Panjál" in a very important point. In that map the beds at the Mozaffarábád bend of the Jhelam, north of the Mari (Murree) group, are classified as belonging to the Subáthu group. These beds consist of limestones mingled with a few slaty shales, and very strongly resemble the rocks of the latter group. At my first visit I found a few nummulites near the junction of the red clays and limestones, and I thought that they must have been derived from the latter. Last spring, however, I again crossed the river at Mozaffarábád, and after making a very careful examination of the limestone group, I came to the conclusion that this did not contain nummulites, but that those which I found on my previous visit must have been derived from the red clay series.

The limestones and slates of Mozaffarábád agree very closely in general mineralogical characters with the Uri limestones described in my paper on the Pír Panjál, and I have therefore come to the conclusion that the two must be referred to the same horizon. It is not possible, however, to trace the two continuously together, as to the south-east of Mozaffarábád the slates of the Káj-Nág come into contact with the red rocks of the Mari group.

Slates similar in character to those of the Káj-Nág range, associated with newer rocks, occur in the Hazára district to the south of Mozaffarábád, which are now in course of examination by Mr. Wynne. It seems therefore probable that the limestones of Uri and the slates of the Káj-Nág sweep round the angle of the Mari rocks at Mozaffarábád, and are continuous with similar rocks forming the ranges of the Hazára district, which have a north-easterly in place of the normal north-westerly Himalayan strike.

In the above referred to map other Subáthu rocks are represented to the west of Dewal; these are on the strike of the Mozaffarábád limestones, and it is not improbable that they also belong to the same horizon. It must, however, be borne in mind, that further south to the west of Pindi on the same strike, distinctly nummulitic limestones occur, and as there is great confusion of the rocks in many parts of this line, the position of those to the west of Dewal must for the present remain unsettled.

In my last map[1] the rocks on the left bank of the lower part of the Sind valley were left uncolored; an examination of these rocks shows that they consist entirely of the slates and sandstones of the Panjál series, having a north-easterly dip at the Dal Lake. The rocks up the Trál valley, between Srinagar and the Lidar valley, were similarly left uncolored in the same map. These rocks I now find consist entirely of slates and sandstones, mingled here and there with the Pír Panjál amygdaloids; they must doubtless all be referred to the Panjál series. These same rocks I have traced northwards to the section which I took last year between the Lidar and Sind valleys, and it is therefore apparent that the whole of the rocks

[1] Geology of Kashmír, Kishtwár, and Pangi.

north of the ellipse of carboniferous limestone which occurs near Srinagar must be referred to the Panjál series.

On the opposite side of the valley of Kashmír, at Gúlmarg, I have carried a section up to the central core of gneiss, which here occupies the highest point of the range, and is continuous with the gneiss shewn in my last map to the south-east of the Jhelam valley. The gneiss above Gúlmarg has the same relation to the slates and sandstones as has the corresponding gneiss of the Pír Panjál pass to the same series. This relation and the inferences drawn from it will be found in my last paper.

II.—Sind and Tilail Valleys.

The greater part of the Sind valley section has already been described in my last paper. During the past summer, however, I had occasion to re-traverse this line, and some further remarks on the section which occurred to me during this second visit have been added in the present paper. My great object in this journey was to trace the limestone series of Sonamarg and Amrnáth (Ambarnáth) to the north-west, and I shall describe below the sections as they were met with on my route: it may be well in the first place to mention the route I took.

Starting from the valley of Kashmír, I travelled by the Ladák road as far as the town of Drás; from thence I turned off to the westward, crossing the pass into the Tilail valley; I then followed the Kishenganga[1] river as far as Gurais, making several detours to the northward. From Gurais I returned to the village of Bodagrám in Tilail, and from thence struck across the hills in a south-easterly direction *viâ* the Lahani and Gadasir valleys to Sonamarg in the Sind valley. A separate trip from Kashmír to Gurais along the Astor road enabled me to connect the north-westerly extremity of the Tilail section with the previously known rocks of the valley of Kashmír.

At page 47 of my last paper I referred to a mass of gneiss mingled with a few bands of limestone which occurs in the lower part of the Sind valley, south of the village of Wangat. I then suggested the possibility of this gneiss being newer than the slate series. A further examination of these rocks has, however, led me to come to the conclusion that the gneiss series really underlies the slate and amygdaloidal series, and that the former must consequently correspond in position with the gneiss of the Pír Panjál. The peculiarity of the Sind valley gneiss is, that it contains some beds of unaltered blue limestone and others of white crystallised limestone; the occurrence of this limestone with the gneiss cannot, however, of itself, I think, be regarded as of any importance as regards the age of the rock. Very similar limestones occur in the gneiss of the Bhútna river in Pangi, which were noticed in my last paper.

Above this mass of gneiss I have no additional remarks to make on the Sind valley section, until we come to the great limestone series of Sonamarg. In rela-

[1] The name of the Kishenganga river does not appear on the map. It should be applied to the river which rises in Tilail above Gújrond (Goojrond), and from thence flows to Gurais.

tion to this series I must observe that in my last published map, the boundary lines of this formation on the Drás side of the Zoji pass were taken from unpublished notes left by the late Dr. Stoliczka; a traverse of this route by myself has shown me that some error had crept into the map as to the position of the north-eastern boundary of the Zoji-la slates which was put much too near the pass; this error was most probably due to some misinterpretation of the notes left by Dr. Stoliczka.

As I had not proceeded beyond Sonamarg when I wrote my last paper, I shall take up the section from that place; the preceding descriptions of this section will be found at page 46 of my last paper of which this must be taken as the sequel.

An anticlinal axis traverses the Sonamarg limestone series in a north-westerly and south-easterly direction near the village of Thájwaz; this axis, as is noticed by Dr. Stoliczka,[1] is continued from thence along the course of the Sind river as far as the halting place of Báltal, at which point it bends round abruptly to the southward. As we ascend the Sind valley from Sonamarg, we find higher and higher beds forming the exposed base of the anticlinal, till at Báltal the rocks consist in great part of white dolomitic limestones like those of Amrnáth cave, described in my last paper. A great portion of the lower white dolomitic rocks of the latter place are replaced in the Sind valley by blue banded limestones intermingled with slates.

Immediately above Báltal, the limestones, with a north-easterly dip, are succeeded by the slates of the Zoji-la, with the same dip: these slates soon become nearly vertical; they are often columnar or bacillar in structure, and contain bands of limestone; immediately north of the Zoji pass, we find a band of this intercalated limestone some fifty feet in thickness; this limestone is underlaid by slates, and again appears further down across an anticlinal flexure in the same slates. Alternations of slates, micaceous sandstones, and quartzites, with occasional bands of limestone, continue along the Drás road, till we get within half a mile of Mataian: these rocks in many places are greatly disturbed by contortion.

Above Mataian we come upon blue limestones underlying the slates; the former are again underlaid by white dolomitic limestones like those of Amrnáth; these limestones indeed bend round to the east of the Gúmbar (Goomber) stream to meet those of the latter place.

We have already seen that the triassic limestones and dolomites of Sonamarg, according to my view, underlie the slates at Báltal and Mataian, in which respect the sequence here exactly agrees with that which I have shown in my last paper[2] to occur more to the eastward at Panjtarni. Further, we have seen that a distinct anticlinal flexure traverses the limestone series at Báltal, which disproves the

[1] Scientific results of Yarkand Mission—Geology, p. 12.

[2] Page 45.

alleged superposition of the triassic limestones on the Zoji-la slates.[1] Across the Zoji-la pass, however, owing to the great amount of contortion which the rocks have undergone, the sequence cannot be clearly traced, though I incline to think that the whole of the rocks between Báltal and Mataian are newer than the triassic limestone series. Beyond the Zoji pass, however, there occur on the road a few blocks of a gneissoid rock coming from the eastward, which may show that certain older rocks are thrown up by faults within the presumed triassic area. I have no positive proof, however, that such is the case, and I do not therefore desire to lay any great stress one way or the other upon the presence of a few gneissoid rocks within this area.

At Mataian there is a small fold in the white dolomitic limestones, and below this the same rocks continue with a southerly or south-westerly dip to the great bend in the Gúmbar river. At this bend the triassic series is faulted against another great rock series, which has a northerly dip; for a short distance below this bend the river runs along a faulted anticlinal axis, while further down the dolomitic series is continued to the eastward a little to the south of the river: the dolomitic rocks have in this direction been traced a little to the eastward of Drás. The rocks[2] to the north of this fault have a general blackish color when seen from a short distance, which contrasts most strongly with the white colored dolomites to the south. These slaty rocks to the north and east of Drás are abruptly cut off by a great mass of crystalline rocks. These crystalline rocks are mentioned by Dr. Stoliczka in his "Geological Observations in Western Tibet" under the name of syenite, and are traced down the Suru river. In the latter area, according to Dr. Stoliczka, this rock contains large crystals of hornblende and diallage, with occasional nests of epidote and serpentine, together with grey quartz, and albite, and occasionally orthoclase. A rock of this composition is of course rightly named syenite: at Drás, however, the composition of the rock appears to have changed; in hand specimens, which I collected, its constituents are quartz, brown uniaxial mica, and one or two kinds of felspar, and apparently no hornblende. The Drás rock, therefore, seems to be a true granite, and the same composition prevails in these rocks as we proceed to the east.

A portion of the slaty rocks of Drás was considered by Dr. Stoliczka (sup. cit., p. 349) to be of silurian age, while another portion was considered to be of

[1] There appears to be some confusion in Dr. Stoliczka's account of this section. At page 349 of his "Geological Observations in Western Tibet," he observes, "these rocks (Zoji-la slates) are *overlaid*—neglecting interruptions—by limestones and carbonaceous slates," making no mention of the anticlinal in the limestones. At page 12 of the Geology of the Yarkand Mission, he observes that the limestones near Sonamarg have 'a northerly dip on the right bank of the valley,' and immediately afterwards he says, that some four miles to the east on the same strike these limestones which dip towards the slates are *underlaid* by the slates, which is, so far, contradictory. In my last paper on Kashmír geology (p. 45), I assumed from Dr. Stoliczka's first account that there must be inversion. Now that I have visited the spot, however, it appears to be a regular sequence, though somewhat contorted, but a sequence which agrees exactly with the less disturbed one at Panjtarni.

[2] Mem. Geol. Surv. India, Vol. V, p. 347.

carboniferous age; no fossils were, however, discovered. We shall subsequently see that these Drás slates are the equivalents of the Pír Panjál rocks of Kashmír, and therefore appear to be the equivalents mainly of the silurians, though there is no reason why some of their higher beds should not be carboniferous. The same rocks may be traced in a south-easterly direction to Kurtse, where they overlie the gneiss of Suru.

Near the town of Drás itself the slate series has generally a very massive character, showing at a short distance but very indistinct signs of stratification; the rocks consist mainly of brown or purple sandstones, and black, brown, green, and brick-red slates and shales. To the westward of Drás, the same rock-series is continued up the Muski stream, with a generally northerly dip; a little to the south of the same stream, we may trace the bold line of cliffs of the triassic dolomites, which have a generally westerly trend, and the same southerly dip which we observed at Drás. Westward of Drás many of the rocks in the slate series consist of light colored ribband-jasper, and there are also numerous beds of conglomerate intercalated with the slates. The pebbles in this conglomerate are sometimes water-worn and sometimes angular, and do not generally exceed four inches in their longest diameter; they consist of quartzites, grits, and slates, some of the two latter of which are very similar in character to the main rock. The occurrence of pebbles in these rocks similar to the matrix, may perhaps be explained in the manner in which Sir Charles Lyell explains a similar feature in the Stonesfield slate of England;[1] he there suggests that the pebbles in the conglomerate, which resemble the main rock, may be portions of the same deposit which have been broken up in shallows and re-deposited. The rocks may, however, have been altered before the formation of this conglomerate.

About twelve miles above Drás on the Muski river, a few thin bands of limestone occur in the slate series; nearer the pass, at the head of the river, black slates and conglomerates are the prevalent rocks.

As we approach the pass separating the Drás and Kishenganga valleys, blue limestones begin gradually to appear at the top of the slate series (which has a southerly dip), till finally at the pass itself these blue limestones form the greater portion of the higher part of the series; still further to the south these blue limestones are overlaid conformably by the buff dolomitic limestones continuous with those south of Drás, in which Dr. Stoliczka found triassic fossils.

We therefore find that at the head of the Muski stream a very different condition obtains to what we found at Drás; at the latter place we found a fault separating the Drás slates from the triassic dolomites, while in the former place the two series are connected by an intervening series of blue limestones, the whole being apparently conformable. The inference from this is *firstly*, that the fault which occurred at Drás has here died out, *secondly*, that the intermediate blue limestones belong approximately to the carboniferous series, and *thirdly*, that the Drás slates belong approximately to the silurian series. The carboni-

[1] Student's Elements of Geology, p. 323.

ferous limestone I estimate here at 3,000 feet in thickness, and the triassic as from 4,000 to 6,000 feet.

Down the Tilail valley, nearly to the Búrzil (Boorzil) river, the blue carboniferous limestone continues a little to the south of the Kishenganga, overlying the slates, and itself overlaid by the dolomitic limestones of the trias; these latter, more especially in the pass between Drás and Tilail, from their uniform and homogeneous character, weather into grand tower-like cliffs and crags, showing very little signs of stratification. The banded carboniferous limestones, on the other hand, which generally contain intercalated beds of slate, weather into bands parallel to the stratification.

On the right bank of the Kishenganga river in Tilail, there is an anticlinal axis a little north of the limestone series, and again, beyond this, a synclinal axis; in this synclinal axis there occurs a broken line of presumably carboniferous limestone. To the north of this synclinal I have traced the slate series, which has a generally southerly dip, to the summit of the Tilail watershed; black slates here form the higher portions of the series, while sandstones and grits are more common lower down. Lower down the Kishenganga valley, during a shooting tour made in 1874, I also traced the same slate series to the watershed of the Kelah Shai and Satani streams; it is therefore apparent that this silurian slate series extends to the northern watershed of the Muski and Kishenganga valleys, from Drás to the Búrzil river. I may mention that in the fine-grained black slates which occur high up in the Kelah Shai valley, I found in 1874 obscure organic impressions which I thought might possibly belong to *Graptolites*. I have unfortunately since lost these specimens, so that I cannot confirm this opinion.

Returning to the middle of the Tilail valley, near the village of Bodagrám, we find that green amygdaloids like those of the Pír Panjál are of common occurrence in the slate series, from which I think we may safely conclude that the Drás and Panjál series are of the same age. This coincides with the inference drawn as to the age of the Drás slates from their relations to the triassic dolomites.

We have now to take an oblique cross-section through the great limestone series, from the village of Bodagrám in Tilail to Sonamarg in the Sind valley. In crossing the ridge on the left bank of the Kishenganga, separating that river from the Lahani stream, we first pass over a continuously ascending series of light blue carboniferous limestones with a southerly dip; as we descend on the opposite side of the ridge into the Lahani valley, we find these blue limestones succeeded conformably by bands of white dolomitic limestones, pure blue limestones, green slates, and a peculiar white slaty limestone. On the Lahani stream there occurs a thick band of brownish slates; these and other slates intermingled with a few bands of limestone, with the same southerly dip, extend halfway up the ridge separating the Lahani from the Gadasir stream; here we find the slates overlaid by white, buff, and blue dolomites and limestones. Crossing the ridge into the Gadasir valley, we come upon a synclinal axis, and as we descend we cross the same beds in a reversed direction. The lowest of these northerly dipping beds,

however, exposed in the Gadasir stream are the dolomites and limestones, and not the underlying slates seen in the Lahani stream.

It will, I think, be evident from this section that the last-mentioned dolomites and limestones must be the representatives of the pure white triassic dolomites which occur further to the east; it is, however, not quite clear whether the brown slates in the Lahani valley belong to the carboniferous or to the triassic series; as, however, dolomitic limestones and a whitish calcareous slate occur below these brown slates, and as the thickness of the carboniferous limestones, north of the Lahani stream, is about equal to that which occurs more to the eastward, I have thought it probable that the slates near the Lahani stream and the overlying dolomites and limestones all belong to the triassic series, and I have accordingly so colored them in the map. The slates which occur in the middle of the limestones not improbably indicate that we have here a littoral deposit in a subsiding area, and that as subsidence went on more rapidly, limestones were again thrown down over the slates.

As the triassic series has not in this place the homogeneous structure which is so characteristic of it, further to the eastward, the general appearance of the rocks is very different; they do not weather out into the craggy peaks like those of Amrnáth and Drás, but into parallel hollows and ridges, accordingly as the harder or softer beds are more prevalent: in this respect resembling the triassic series at Sonamarg, as described in my last paper.

Reverting now to our section, we find on the left bank of the Gadasir stream, tall cliffs composed of the amygdaloidal rocks of the Pír Panjál series, which I have traced to the south-east into similar rocks forming Shalian ridge, which were described in my last paper; to the north-west these rocks continue on towards Gurais, where I shall have again to refer to them. The boundary between the triassic and silurian rocks continues up the Gadasir stream, and by the two small lakes called Kishan-Sar at the head of the Raman stream, and thence again down the Nichinai stream, till it reaches Thájwaz, where it was described in my last paper. White dolomitic limestones are most prevalent at Kishan-Sar, but towards Thájwaz blue limestones with slates are more prevalent; corals and crinoids are extremely abundant in the dolomitic limestones near the head of the Gadasir stream, the rocks at this place having evidently once formed part of an old coral reef.

For some way down the Gadasir stream, the junction between the slate and limestone series is a faulted one; this is rendered evident by the fact that the higher dolomitic limestones in the Gadasir valley rest against the nearly vertical silurians, while at Thájwaz the limestones in which Dr. Stoliczka found a triassic Ammonite dip towards the older silurians. Lower down the Gadasir stream, however, as we shall see at Gurais, the fault dies out, and there is an apparently uninterrupted succession from the presumably silurian slates to the triassic dolomites.

As accessory evidence in regard to the Gadasir-Nichinai fault, it may be observed that along the whole of this junction, a line of springs of extremely pure

water bursts forth. These springs, which have a temperature of about 50° F., in great part supply the two small lakes called Kishan-Sar above referred to. These lakes are situated at an elevation of a little short of 13,000 feet above the sea; and my guide from Tilail told me that they never freeze, even in winter, which is owing to their being supplied by these springs whose temperature I presume to be nearly constant. I at the same time paid a visit to another small lake called Gurasar-Nág, within the silurian area, and consequently off the line of springs; in this lake, which is situated at about the same elevation as the others, I found, at the latter part of August, huge masses of snow floating about in the water, and the temperature of the water at freezing point, while the temperature of the water of Kishan-Sar I estimated at over 40° F., though glaciers drain into it.

From these facts there can be little doubt but that the above referred to line of springs is of very deep-seated origin, which is strongly in favor of their being forced up from the depths of a fault between the limestone and slate series.

I may mention in passing that the mountain lakes referred to above are situated in hollows, the mouths of which are dammed by the moraines of old glaciers, of the former existence of which there are here abundant evidences.

Returning once more to our section, it firstly remains to mention that the band of carboniferous cherty limestone, described in my former paper as occurring at the top of the slate series at Gaggangan (Gungungan) in the Sind valley, and thence continued to the north-west, dies out across the watershed of the Sind valley, and the amygdaloidal silurians of the Shalian ridge consequently come into immediate contact with the slates of the Sind valley, though I am unable to say whether or no the fault is continued.

It now remains to consider the limestone series near Gurais, but before doing so it will be simpler to carry a section from the valley of Kashmír to the latter place, in order that we may the more thoroughly understand the sequence. Starting from Kralpúr (Kralpoora) on the Gurais and Astor road, we find near that village, that the rocks consist chiefly of amygdaloids and slates, an anticlinal axis running through them close to the village. Between Kralpúr and the halting place of Trágbal, the rocks have a general flat northerly dip; the amygdaloidal rocks become relatively fewer as we ascend, and are replaced by green and black or brown slates and sandstones; above Trágbal the rocks consist almost entirely of black slates which preserve the same north-easterly dip till we approach a synclinal axis, near the pass, which is again shortly followed by an anticlinal axis. Descending from the pass towards Kanzalwan, after a few miles we come upon a band of micaceous and gneissoid rocks, with a northerly dip, apparently overlying the black slates. It is, however, quite possible that a fault may occur at the base of these gnéissoid rocks, and they may consequently be at the base of the slates. There is, I think, from its mineral character, little doubt but that this gneiss is the same as that of the Pír Panjál, which I have considered in my former papers to be at the base of the slates. Irrespective of any other considerations, it would be extremely improbable that a band of gneiss, in localities so far apart

as this and the Pír Panjál, always occurred in the middle of the slates, whereas it would be extremely probable that it should occur always at their base.

Beyond this gneiss, still descending the stream, we find black slates conformably overlying the crystalline band, while towards Kanzalwan a few of the Pír Panjál amygdaloids occur intermingled with the slates, showing that we are still in the silurian series. Leaving Kanzalwan, the rocks along the Kishenganga river consist of the peculiar bluish-green slaty sandstones which were noticed in my last paper as occurring below the carboniferous limestones at Chandanwari, in the Lidar valley. As we approach Gurais, these rocks are overlaid by blue limestones with the same north-easterly dip; the blue limestones are followed by blue and white limestones in bands, the whole being capped by white dolomites like those of Amrnáth. In 1874, during the shooting-trip previously mentioned, I found at the base of these limestones a larger species of *Clymenia*,—a genus characteristic of the upper devonian.

From the conformable position of this limestone series on the top of the slates, and from the occurrence of the above-mentioned fossil, it seems probable that we have here a regular ascending rock series, from the silurian to the trias inclusive; I cannot, however, put in any distinct devonian group, or draw any arbitrary boundary between the carboniferous and the trias. I have accordingly merely coloured in the former rocks as forming a band corresponding to their average width in other localities, which I have made to die out towards the south-east, where, as we have seen, there is a faulted junction between the slate and the limestone series, and where the carboniferous or lower limestones are probably wanting.

Near Gurais bands of a conglomerate occur in the slate series similar to the conglomerate of the Pír Panjál range; this conglomerate contains pebbles of granite or syenite, similar to that of Drás, which rock must, consequently, be older than the slates, and must have existed in its present condition at the time of the deposition of the latter. Pebbles of the same crystalline rocks occur in the bed of the Búrzil river, which seems to indicate that these rocks are continued to the north of the Tilail watershed into the higher valley of the Búrzil. It also seems probable, that these same granitoid rocks have a great extension to the east, forming the rocks on the right bank of the upper Indus at Lè, where they are variously referred to by Dr. Stoliczka as "granitic and syenitic rocks" [1] and "syenitic gneiss" [2]. In the latter districts, they were considered by Dr. Stoliczka as forming, in all probability, part of the silurian series; there being apparently in the Lè district no break between these rocks and overlying shales supposed to be of carboniferous age.

There is, however, quite a possibility of there being a hidden unconformity in the Lè district, which would correspond to the unconformity at Drás, shown by the crystalline pebbles in the slates, and I would suggest that it may possibly turn

[1] Geological Observations in Western Tibet, p. 348.

[2] "Scientific Results of Yarkand Mission"—Geology, p. 15.

out that some of these Drás and Lè crystallines are the representatives of some of the crystallines in Suru and Lahúl, where there is a probability of rocks of two ages being intermingled.[1]

The unusually wide area over which the Pír Panjál conglomerate (if that of Pangi be the same) extends in the slate series, is a very remarkable circumstance, and must clearly be due to some very wide-spread cause. In the Pangi district I have elsewhere stated that it seemed to me to be extremely probable that ice action has been connected with its production, and considering its wide distribution in Kashmír, I am beginning to think whether we must not have recourse to some similar transporting power there, though I have at present no positive proofs to bring forward. The occurrence of gneiss (or syenite?) pebbles in the conglomerate of the Pír Panjál, which, we have seen, cannot belong to the gneiss of that district, may be considered as tending towards the hypothesis of ice-transport.

It now remains to say a few words regarding the area between the Sind valley and the Trágbal and Gurais road. It will be found from my last paper that with the exception of the gneiss in the Sind valley, all the rocks in the valley of that river below Gaggangan belong to the silurian series; the same rocks, with the exception of a few others of carboniferous limestone, bound this area to the southward along the vale of Kashmír; similar rocks bound this area to the north-west on the Gurais road, with the exception of the band of gneiss noticed above; on the north-east the same rocks underlie the limestone series of Tilail. It is therefore evident that the area in question is occupied by rocks of the Panjál series, which strike right across it, but that the centre of this area is penetrated by a mass of gneiss running in from the north-west, which, however, does not reach into the Sind valley. On a former occasion I have found this gneiss occurring high up in the valley to the east of Kralpúr, and on the northern flanks of Haramúk (Haramook). It seems therefore evident that this band of gneiss dies out somewhere on the north-western side of Haramúk, and that the rest of the area consists of the rocks of the Pír Panjál. The area has accordingly been colored in on the map, though the boundaries of the gneiss must be only regarded as an approximation to the truth.

A general glance at the map of the north-eastern side of Kashmír, will, on the whole, show us that the geological features of the country are very similar to those of the Pír Panjál and valley of Kashmír, as treated of in my last paper. We there found that the centre of the Panjál range seemed to be an anticlinal axis, flanked on the outer side by limestones considered to be of carboniferous age, and followed on the inner side by the synclinal axis of the vale of Kashmír containing undoubtedly carboniferous rocks.

Similarly, on the Gurais road, we find an anticlinal axis showing gneiss, followed by the synclinal of the Gurais valley, containing carboniferous and triassic strata again underlaid by silurians to the north-east.

[1] Rec. Geol. Surv. India, Vol. XI, p. 60.

To the south-east of Haramúk, this northern anticlinal is not so well marked, as no gneiss is shown in the section; while still further to the south-east, as at Palgám in the Lidar valley, the anticlinal has quite died out, and is replaced by a local synclinal, in which there rests an outlier of carboniferous strata.

The synclinal in the silurians at Gurais, containing carboniferous and triassic strata, is a well marked feature, extending from the former place to Panjtarni and Drás towards the south-east. In many places, however, it will be observed that the original relations of this synclinal have been disturbed by faulting, but not to such an extent as to obscure the general features of the system. To the north of this great synclinal ellipse, we have another slight synclinal containing carboniferous strata in the midst of silurian rocks.

It will have been observed in the course of the preceding sections, that the slates of the Zoji-la, lying in a synclinal ellipse of the triassic limestones, are not represented in the section taken from Tilail to Sonamarg; the synclinal being contracted at this point. It is therefore apparent that these slates must die out gradually between the Zoji-la and that point; this has accordingly been so represented in the map, though the north-western termination of these Zoji-la slates is only approximately represented.

In concluding this sketch, I wish to add a few words regarding the probable age of the strata overlying the silurian series, in the Tilail and Drás districts, and their relations to the great limestone series of the valley of Kashmír. I would premise that fossils are of extremely rare occurrence in this series, and that therefore no precise distinctions as to the age of the different beds can be drawn, but only the general homotaxis of the series can be roughly indicated. I have already observed in my last paper, that in the fossiliferous strata of the more eastern Himalaya, the late Dr. Stoliczka found that no distinct devonian or permian periods could be determined from the fossil evidence, but that strata containing a fauna with a distinct silurian *facies* were immediately followed by other strata containing a fauna with a carboniferous *facies*, and the latter again by a triassic fauna. The absence of a distinct devonian and permian period cannot here be explained, on the supposition that during these periods the area was dry land, since (unless there be concealed breaks of which we have no knowledge) there seems to be an uninterrupted succession of strata; and we are therefore driven to conclude that the strata classed by Dr. Stoliczka as silurian, carboniferous, and triassic, must be the representatives of the whole of the European series from the silurian to the triassic inclusive; and that the same probably holds good in the Kashmír area.

On these grounds it would not appear surprising, if we were to find a commingling of the fossils of all these different periods, to a certain limited extent; and such appears to be certainly sometimes the case in India, since Dr. Waagen[1] has described the occurrence of Ammonites associated with Goniatites in the carboniferous strata of the Salt Range, clearly showing a blending of the carboniferous and triassic faunas.

[1] Mem. Geol. Surv. India, Vol. IX, pt. II.

Returning now to our Kashmír limestones, we find that in the valley of Kashmír at Eishmakám and near the Marbal pass, as well as in a few other places, distinctly carboniferous fossils have been found, generally low down in the series; a few similar fossils have also been found at the base of the limestone series of the north of Kashmír, near Shísha-Nág, which seems to correlate the bases of the two local series. Further to the westward at Thájwaz, a triassic Ammonite was found by Dr. Stoliczka somewhat low down in the limestone series, but how low down I am unable to say, because the junction between the limestone and slate series is here a faulted one. A little higher up in the same series I have myself found corals and crinoids.

At the top of the Gadasir stream, I found what seems certainly to be a *Chætetes* in considerable quantity; and at Sonamarg I found one large mass of a *Cyathophyllum* or some closely allied genus. Now, the genus *Chætetes* has been hitherto known in the Himalaya from the Muth series[1] only, which is supposed to be the representative of the European silurian, while we now have it on a line of beds which have yielded a triassic Ammonite. In Europe the genus attained its maximum in the carboniferous rocks, but also ranged both above and below that formation.

Cyathophyllum also, according to Dr. Stoliczka, has hitherto been found only in the Muth series in the Himalaya; in Europe this genus ranges from the silurian to the trias.

As far as these two genera go, therefore, it seems that no evidence of the age of the rocks in which they occur can be obtained. The discovery of these in the triassic series of India shows that they had a wide range in time here as in Europe.

Again, near Drás, in the dolomitic series, which corresponds to some parts of the limestone series at Thájwaz, very characteristic upper triassic fossils were found by Dr. Stoliczka.[2]

Turning now to the same great limestone series at Gurais, we find that here we have an apparently continuous series from the Panjál slates through the limestones; and that quite at the base of these limestones a species of the genus *Clymenia* was found which is characteristic of the upper devonian of Europe.

Taking, therefore, the whole of this evidence, it is quite clear that the base of the limestone series of Kashmír is of carboniferous, and from the evidence of the *Clymenia* perhaps partly of upper devonian age. The higher dolomitic beds, on the other hand, are clearly of upper triassic age. The only question is where to draw the boundary between the two periods.

Now, at Thájwaz, where the Ammonite was found, and where the junction is faulted, the strata have been colored in the map as of triassic age; it must, however, be said that an anticlinal occurs here, and that no very distinct lithological comparisons are here possible. Moreover, as the whole series is here in sequence,

[1] Stol.: Mem. Geol. Surv. India, Vol. V, part iii, p. 143.

[2] Mem. Geol. Surv. India, Vol. V, p. 349.

and as we have already seen that Ammonites have been found elsewhere in India in strata containing carboniferous fossils, it is not improbable, nay rather it is very probable, that there may here be a mingling of fossils of different periods; and that consequently no hard-and-fast boundaries can be drawn corresponding to the limits of European formations; though at the same time it should be observed that it may hereafter be quite possible to distinguish independent Indian life-zones in these strata, should abundant fossils ever be discovered in them.

In the map wherever there is a regular sequence of strata from the Panjál slates to the upper triassic dolomites of Drás and Amrnáth, the limestones underlying the latter have been classed as carboniferous. Along the faulted line of Thájwaz the whole series has been referred to the trias from the evidence of the Ammonite, which, as above said, may be doubtful; and there may therefore be a few carboniferous beds at the base of the anticlinal, while at the same time some of the higher slates may be of carboniferous age.

We may also observe that since the limestones of the valley of Kashmír itself, which contain numerous carboniferous fossils at their base, are in many places thicker than the carboniferous band in the limestone series of the north of Kashmír, it is more than probable that some portions of the former are the representatives of the triassic series. At Mánasbal[1] this has already been proved to be the case, from the identity in mineral character of the white dolomites at the top of the series in that place with the similar rocks of Drás and Amrnáth. In the south-eastern extremity of the valley of Kashmír, the whole of the limestone series has the same mineralogical composition throughout, and the higher beds have hitherto yielded no fossils. We have therefore no direct evidence to connect the upper beds there with the trias of Drás, and they must therefore remain on the map as of carboniferous age, until evidence can be produced to the contrary.

Finally, we must come to the conclusion that the Kashmír limestone series forms an unbroken sequence of strata, which must be the equivalents of all the European strata from the upper devonian to the upper triassic inclusive; but as, with one exception, no devonian or permian fossils have been discovered, the strata have been colored on the map as carboniferous and triassic only.

From the distribution of the limestone series in Kashmír, it seems pretty evident that these strata were once connected and extended over the whole area, and have been brought into their present form by disturbance and denudation.

The strata overlying the triassic dolomites of the Zoji-la being sandy and clayey in composition, were probably deposited in a shallower sea than that in which the older limestones were laid down; and since no newer strata are known in this area, it is possible that the bottom of the sea was being upheaved at the time of the deposition of these slates, and that the area has not subsequently been submerged.

[1] Rec. Geol. Surv. India, Vol. XI, p. 47.

The local occurrence of clayey and sandy rocks in the limestone series on the horizon of pure limestones may also suggest that the sea in which these limestones were laid down was in places shallow, and near to land; the presence of coral reefs also attests either the presence of land, of a shallow sea, or of a sea filled with atolls. Where the ancient land surfaces were, we have at present no mean of indicating.

III.—Traces of old glaciers in Kashmír.

As there has been considerable discussion carried on in the "Records" of late concerning the supposed glaciation of parts of the Upper Punjab, I have thought it would not be out of place to state here any facts which I have observed as to evidences of former glaciation in Kashmír and the neighbouring mountains.

I will first observe that I have nowhere observed any traces of glaciation in the valley of Kashmír itself. I have already observed in my last paper,[1] that I cannot agree with Professor Leith Adams[2] in considering the Báramúla gravels as affording any evidence of former glaciation; and I know of no other deposits in the valley which could possibly be considered to be due to the same agency. Neither have I seen any traces of erratics, perched blocks, *roches moutonnées*, or scratched rock-surfaces within the limits of the valley. I may add that I think it almost certain that the Báramúla gravels are much older than the old glacial moraines of other parts of Kashmír, which are always entirely undisturbed by tilting.

The lowest elevation in Kashmír at which I have observed glacial phenomena is in the Sind valley near the village of Kúlan, (marked in the map issued with my last paper), at an elevation of about 7,000 feet; here I have seen very distinct glacial striation. Mr. Drew,[3] moreover, mentions the occurrence of a well grooved *roche moutonnée* near the same place at an elevation of about 6,500 feet above the sea level, or 1,500 feet above the level of Srinagar. This is the lowest spot in Kashmír, where there seems to be undoubted evidence of former glacier action.

Above this elevation traces of old glaciers are extremely numerous in the Kashmír Himalaya; and I will here only notice one or two well marked instances.

At Gúlmarg, on the Pír Panjál, many of the hillocks of detrital matter stretching out into the valley seem undoubtedly from their shape to have formed part of an old glacier moraine, though I have not succeeded in obtaining any grooved rocks; the elevation of this place is somewhat short of 8,000 feet.

At Sonamarg and Thájwaz, in the upper Sind valley, there is an undulating plateau, at an elevation of about 9,000 feet, which is composed entirely of detrital matter, to a depth in places of at least 300 feet. This plateau has been admirably described at page 220 of Mr. Drew's above-quoted work on Kashmír, and is there clearly shown to have once formed an old glacier moraine. I have found glacial

[1] p. 33.
[2] Wanderings of a Naturalist in India, p. 171.
[3] Jummoo and Kashmír Territories, p. 220.

scratches on some of the angular blocks of this moraine. The blocks in this moraine consist almost entirely of the amygdaloidal rocks of the Shalian ridge, while the moraine itself rests in a hollow of the Sonamarg limestone. At an elevation of about 2,000 feet above the Sonamarg plateau three small glaciers still nestle in sheltered ravines on the northern aspect of the Shalian ridge. Mr. Drew thinks it probable that the whole of the Sind valley nearly as far down as Kangan was formerly occupied by a glacier—a conclusion with which I agree. The hill of limestone separating the village of Sonamarg from the valley of the larger Thájwaz glacier, represented at page 219 of Mr. Drew's book, is at its lowest point some 500 feet above the level of the Sonamarg moraine, and has a peculiarly rounded appearance, which suggests the probability of this hill having been once buried beneath the ice of the old glacier.

On the Ladák side of the Zoji pass, we find at Drás, which has an elevation of some 10,000 feet, two huge embankments of detrital matter, some four or five miles in length, extending from the crystalline ridges of the north into the Drás valley, and consisting almost entirely of boulders of the crystalline rocks strewing the surface of the slate rocks of Drás. From the form of these masses of detrital matter, I think that they are certainly due to former glacial action; which opinion is strengthened by the great distance over which the boulders have travelled, and by the very slight fall of the ground on which they lie,—a fall so slight that I cannot think these huge blocks could have possibly been moved along it by the action of water alone, especially as there is no great river along the line of their course.

It now remains to consider certain granitoid blocks in the Jhelam valley below Báramúla which Colonel Godwin-Austen[1] suggests may have been brought into their present position by the aid of ice-action. In discussing the question of the glacial or non-glacial origin of the deposits in which these blocks occur, it will be necessary to go somewhat into the history of the Jhelam valley.

On referring to the outline map accompanying my paper on the Geography of the Pír Panjál, it will be seen that there are two masses of gneiss, one on either side of the valley, above and below Rámpúr, but which do not extend down into the stream itself. It is from these masses of gneiss that the boulders in the river bed have been derived; and it only remains to consider the means by which they have attained their present position.

The first of these masses of gneiss occurs a little to the south of the town of Naushara; this gneiss extends into the watershed of the mountain torrents, which descend into the Jhelam valley, so that it is quite possible for blocks of it to be carried by water into the Jhelam. Immediately below Naushara we come upon an alluvial deposit in the river, which is chiefly composed of blocks of this gneiss, which, as being harder, remains after the slate boulders from the neighbouring cliffs have been ground to powder.

At Rámpúr this alluvial formation contains gneissic blocks, some of which are as much as 15 feet in diameter; the whole formation is at least one hundred

[1] Proc. Geol. Soc., London, 1864, p. 383.

feet in thickness on the left bank of the river. The included blocks are all more or less rounded and water-worn, while the matrix in which they are imbedded is here but little stratified. As we descend the river, the blocks of gneiss continue to decrease in size, till we come upon the sharp bend in the river below Rámpúr; here a fresh stream of gneiss blocks has come down a tributary stream from the second gneiss mass in the Káj-Nág range; some of these blocks have a long diameter of upwards of 20 feet.

Still continuing our survey down the river, we find the gneiss blocks again becoming smaller and smaller, and half-way to Uri the alluvial deposit is seen to be most distinctly stratified. All the gneiss boulders have their long axes inclined up the stream and towards the river-bed at an angle of about 30 ; so that one of the flat sides of each boulder is opposed to the flow of the stream, as we find to be the case in any deposit of modern river pebbles.

The summit of the alluvial formation is level, forming high-level plateaux on either side of the river. At Uri we find a similar plateau, some 200 feet in thickness, formed of the red Sirmúr rocks of the neighbouring hills; the pebbles in this deposit are rounded, and have the same relative position in regard to the stream as the gneiss blocks higher up. A few small gneiss blocks are found in the Uri deposit.

Below Uri the same formation runs along either bank of the river with the same "hanging level" often between 200 and 300 feet in thickness; a few gneiss pebbles occur in this deposit; the other boulders consist of the Sirmúr sandstones, some of them of large size.

A few miles above Hatian we again find a great number of rounded boulders of porphyritic gneiss embedded in the alluvial formation, some of which have a long diameter of over 10 feet. It is probable that these blocks have come down across the Jhelam from the peaks of the Káj-Nág immediately to the north, where the same gneiss doubtless occurs, though I do not know its correct position. Small blocks of this gneiss can be traced from Hatian as far as the bend of the river at Mozaffarábád.

It will be gathered from the above observations that the whole of the gneiss blocks in the Jhelam valley have followed the course of tributary mountain streams, have not been carried across intervening ridges, and are imbedded in an aqueous formation. Further, there are not the slightest traces of glacial action on any of the hard slate rocks in the Upper Jhelam valley, which ought to have existed, as they do in other places, had glaciers extended into the Jhelam valley.

Again, the Jhelam itself is able to roll and carry down the gneiss blocks which now lie in its course, and *a fortiori* the mountain streams with a fall ten times as great could easily have rolled them down in flood time from their original position.

A tthe same time, I think it extremely probable that many of these glacial blocks were carried some way down the lofty cliffs of the Panjál and Káj-Nág ranges by

ice, at a time when we know that the glaciation of the Himalayas was much greater than at present.

My only point is, that I can see no evidence of glaciers having ever extended down to the level of the Jhelam; and that the gneiss blocks could have perfectly well attained their present position by debacle action.

It will be gathered from the above observations that the Jhelam is now a denuding and not a depositing river, as it was when these alluvial formations were laid down; from which we may probably infer that great changes of level have taken place since the period of those deposits, which may have afforded greater facilities at certain times for the movements of the blocks.

In conclusion, we may state that on the mountains of the north side of Kashmír we have distinct evidence of a former glaciation at an elevation of some 6,500 feet above the sea-level, while on the south side we know of none below 8,000 feet. In the vale of Kashmír itself, and in the lower Jhelam valley, we at present have no distinct evidences of glaciation.

As far, therefore, as this negative evidence goes, it tends to disprove any former glaciation of the outer hills and Upper Punjab, because, if there had been any glaciation of the latter, there would most assuredly have been a far greater glaciation of the valley of Kashmír and the neighbouring hills, since even at equal elevations the present glaciation of the Himalaya increases as we pass towards its central axis.

CORRECTIONS TO MAP.

For "Panjtaria," *read* "Panjtarni."
For "Sonamaro," *read* "Sonamarg."

INDEX.

For "Kareewahs," *read* "Karewahs."
For "Zogi-la," *read* "Zoji-la."

FURTHER NOTICES OF SIWALIK MAMMALIA *by* R. LYDEKKER, B. A., *Geological Survey of India.*

[WITH A PLATE.]

Since my last notice of Siwalik Mammalia,[1] another collection has been received from Mr. Theobald, and a few interesting teeth have been obtained through Mr. Blanford from Sind. Many of Mr. Theobald's specimens have added considerably to our knowledge of the dentition and osteology of previously known species. On the present occasion I shall only very briefly notice the most interesting of the majority of the new specimens, reserving their fuller description for a future occasion, when I shall have an opportunity of giving figures of them. One specimen, however—the jaw of a large monkey—is of so interesting a nature, that I have given a figure of it here, as it would otherwise have been long before I should have been enabled to do so. On the same plate I have likewise had drawn the molars of the *Macacus* and the *Rhizomys* described in my last notice.

Among the rarer specimens is the greater portion of one side of the lower jaw of *Anthracotherium punjabiense*, showing the three true molars.

PRIMATES.

PALÆOPITHECUS SIVALENSIS, n. gen. nobis.

The most interesting specimen in the whole of Mr. Theobald's Siwalik collection is the fragmentary palate of a large anthropoid ape, represented in figures 1 and 5 of the accompanying plate. This specimen is of the highest interest, because, with the exception of a single canine tooth obtained years ago by Dr. Falconer from the Siwaliks, it is the only specimen which affords us any evidence of the former existence of anthropoid apes in India, or indeed, if we except *Dryopithecus* and the smaller genera, in the whole world.

The specimen was obtained by Mr. Theobald from the Siwaliks of the Punjab, somewhere near the village of Jabi, though I do not know the precise locality; it was originally in three fragments, but two of them have been united; and as the fractures are quite recent, I presume that the specimen was broken up by the natives in extracting it from its matrix. The portion that remains shows the greater part of the right maxilla, broken near the centre of the palate, and superiorly at the zygomatic root; the second fragment is a portion of the left maxilla; in the figure the two fragments have been placed in their relative position in the proportions of the palate of the living Orang.

The fragment of the left maxilla contains the complete penultimate, and the bases of the first and last molars. The right maxilla exhibits the entire dental series, from the outer incisor to the last molar; the crown of the incisor, of the penultimate premolar, and the summit of the canine have been broken off; the penultimate molar has the centre of its crown somewhat decayed. The premolars are two in number, which shows that the specimen belongs to the Catarhine

[1] Records, Vol. XI, p. 64.

section of the Primates; all the teeth are well worn, which shows the animal to have been adult at the time of its death.

The molars and canine are arranged in a straight line, and there is a small diastema between the canine and the outer incisor; each tooth of the molar series is inserted by four fangs. In the true molars, the last is the smallest of the three; each tooth carries four cusps on the masticating surface, which form an irregular quadrangle, arranged obliquely to the long axis of the tooth; thus, in relation to a line drawn transversely across the palate, in front of any one molar, we find the antero-external cusp placed first, then the antero-internal cusp, then the postero-external, and lastly, the postero-internal; an imperfect ridge connects the two internal cusps. The crowns of the molars are square or oblong, with their angles rounded off. The one remaining premolar carries two cusps on its masticating surface: both this and the penultimate premolar are remarkable for the shortness of their antero-posterior diameter in relation to the transverse. The canine is a short and blunt conical tooth, with the outer side of the crown rounded, and the inner side bevelled away obliquely from base to summit; no portion of the tooth which remains has been at all affected by wear. The fang of the incisor is small and laterally compressed.

The profile view of the specimen (fig. 1) shows the fangs of the molars and the root of the zygoma which arises above the interval between the first and second true molars; in front of the zygoma there is a channelled hollowing of the jaw, in front of which the fang of the canine bends round in an arch.

From the shortness and bluntness of the canine it is inferred that the jaw belonged to a female individual.

With this description, we may proceed to compare the new jaw with the jaws of other Primates. First, we shall have no difficulty in saying that our specimen does not belong to either of the genera *Semnopithecus*, *Macacus*, or *Cercopithecus* and their allies, because in those genera the cusps on the molars are much higher and sharper, and are arranged in pairs directly transverse to the long axis of the tooth; in addition, the last molar in those genera is always as large, or larger, than the first, and the angles of the molars are square.

In *Cynocephalus* and its allies the teeth have much the same general characters as in the last group, and the last molar is much larger than the first.

As we have already seen, the Siwalik jaw cannot belong to the Platyrhine monkeys, and there only remains, therefore, the group of the *Simiæ*, or the anthropoid apes and man to which it can belong. Now, in all the anthropoid apes and in man the molars are exactly of the pattern of those of our specimen, and there can be no doubt but that the latter belongs to this group. The molars, however, of these apes and of man are so much alike, that it is, I believe, frequently quite impossible to distinguish isolated molars, and we can only therefore arrive at specific or generic distinctions by a comparison of the whole dental series.

Commencing with the lowest of the anthropoid apes—*Hylobates*—we find that the general structure of the molars of that genus is much the same as in the

Siwalik jaw: the premolars are, however, much squarer, the canine relatively longer and sharper, and grooved and concave internally; further, the face in the Siamang is shorter, the hollow in front of the zygoma less deeply channelled, and the canine more approximated to the zygoma, and its alveolus much less arched than in the Siwalik jaw. Finally, as a character of less importance, all the species of *Hylobates* are of much smaller dimensions than the animal to which the fossil jaw belonged.

There now remain only the Orang, Chimpanzee, and Gorilla among the living anthropoid apes, with which to compare our specimen. For this comparison I have drawn up the following tables of the dimensions of the upper teeth in these animals, and in man and *Hylobates*, which it may be well to study before proceeding further.

Table showing dimensions of upper teeth in the higher Primates.

	Siwalik jaw ♀	Simia satyrus ♀	Simia satyrus. ♂	Troglodytes gorilla ♂	Troglodytes niger ♂	Human ♂ European.	Hylobates syndactylus ♂
Antero-posterior diameter of outer incisor ...	0·30	0·30	0·33	0·30	0·30	0·25	0·13
Transverse ditto of ditto ditto	0·19	0·23	0·25	0·25	0·26	0·18	0·18
Antero-posterior diameter of canine ...	0·53	0·46	0·68	0·80	0·62	0·84	0·36
Transverse of ditto	0·51	0·38	0·59	0 60	0·45	0·22	0·27
Length of molar series;	1·87	1·94	2·13	2·70	1·80	1·55	1·21
Ditto of premolars	0·58	0·70	0·74	0·90	0·61	0·50	0·43
Ditto of true molars	1·31	1·26	0·48	1·80	1·20	1·05	0·80
Ditto of penultimate premolar	0·30	0·35	0·39	0·45	0·31	0·25	0·25
Width of ditto ditto	0·50	0·49	0·50	0·64	0·42	0·39	0·25
Length of last ditto ditto	0·30	0·35	0·39	0·48	0·32	0·25	0·25
Width of ditto ditto	0·35	0·49	0·50	0·60	0·44	0·39	0·24
Length of 1st molar	0·45	0·43	0·50	0·55	0·45	0 36	0·28
Width of ditto	0·51	0·45	0·53	0·60	0·49	0·43	0·30
Length of 2nd molar	0·50	0·42	0·49	0·63	0·43	0·38	0·30
Width of ditto	0·51	0·48	0·53	0·60	0·49	0·43	0·31
Length of 3rd molar	0·41	0·42	0·49	0·60	0·35	0·35	0·28
Width of ditto	0·46	0·48	0·53	0·60	0·48	0·41	0·30

Table showing relative lengths of first upper true molar and last premolar in the higher Primates.

	Length of 1st molar.	Length of last premolar.	Difference between these lengths.	Proportionate length of P. M. 4 on scale of Siwalik jaw.	Excess of real over proportionate length.
Siwalik jaw	0·45	0·30	0·15	0·30	0·00
Human ♂	0·36	0·25	0·11	0·24	0·01
Troglodytes niger ♂	0·45	0·62	0·13	0·30	0·02
Simia satyrus ♂	0·50	0·39	0·13	0·33	0·06
Ditto ♀	0·43	0·35	0·07	0·28	0·07
Hylobates syndactylus	0·28	0·25	0·03	0·18	0·07
Troglodytes gorilla	0·55	0·48	0·07	0·36	0·12

The first of these two tables exhibits merely the absolute dimensions of the different teeth; while the second is intended to show the relative lengths of the first molar and the last premolar in the same group. In the fourth column of that table is given what would be the length of the last premolar, if that tooth bore the same relationship as regards length to the first true molar, which it does in the Siwalik jaw. From that table it will be seen that the new jaw is distinguished from the jaws of all other Primates by the relative smallness of the antero-posterior diameter of the last premolar; this shortness is in excess of what occurs in man, in which the same premolar is relatively shorter than in all the other higher Primates; next to man in this respect comes the chimpanzee, then the orang, and last of all the gorilla; and it is worthy of notice that the two species which (excepting man) exhibit the greatest variety in this respect are placed in the same genus. Professor Owen, at page 446 of his "Odontography," notices the small antero-posterior diameter of the premolars in the chimpanzee, as distinguishing it from the orang, and approximating it to man. The new Siwalik jaw, as we have seen, stands on the opposite side of man to the chimpanzee in this respect, and therefore should be still more removed from the orang. The new jaw agrees with that of the orang, gorilla, and chimpanzee, in having the molar series approximately straight, and with no indications of the horse-shoe form which occurs in the human subject; it therefore belongs to a true ape.

Turning our attention once again to the first of the two tables of measurements, we may note in what other respects the fossil jaw resembles or differs from the jaws of the orang, the chimpanzee, the gorilla, and man. In regard to

the relative length of the last molar, we find that the fossil agrees most closely with the chimpanzee and man, in both of which this tooth is much shorter than either of the other true molars. In the orang there is a very slight difference between the lengths of the first and the third true molars; in the gorilla, on the other hand, the last molar is much larger than the first. This difference in the relative lengths of the first and last molars in the gorilla, and the Siwalik jaw, together with the difference which we have already seen to obtain between the last premolars of the same, renders it evident that there is no great affinity between these two, and makes it unnecessary to carry our comparisons any further in this direction.

Comparing the dimensions of the molars of the fossil jaw with those of the female orang, we find that the true molars of the former are larger than those of the latter, and that the united length of the true molars is also greater. When, however, we take the whole molar series, we find that the five teeth of the female orang have an absolutely greater united length than the same five teeth in the Siwalik jaw, this being of course due to the small size of the premolars in the latter. In the chimpanzee, the length of the united molar series is less than in the Siwalik jaw, but the united length of the two premolars is greater, while the length of the three true molars is less: the proportions in the human jaw are in this respect nearest to the fossil.

Again, in the width (transverse diameter) of the base of the outer incisor, the fossil jaw is closer to man than to any of the large apes. In man there is no diastema between the canine and the incisor; in the orang this diastema is larger than in the chimpanzee, which in this respect approaches man. In the fossil jaw this diastema is very slightly larger than in the orang.

The dimensions of the base of the canine are considerably stouter in the fossil jaw than in either the female orang or the male chimpanzee, and approach those of the male orang and gorilla; though the shortness of the crown proves, as we said, that our specimen belongs to a female. In the female orang there is a disk of wear on the posterior border of the canine, which does not occur in the fossil specimen.

The following summary exhibits the points of resemblance and difference between the fossil jaw and the jaws of man, the chimpanzee, and the orang, which are the only three species which are closely related to it:—

MAN.

Resemblances.—Shortness of premolars; small size of last molar and of incisor.

Differences.—Straight line of teeth; large canine and diastema.

CHIMPANZEE.

Resemblances.—Straight line of teeth; shortness of premolars in a less degree; small size of last molar; large canine and diastema.

Differences.—Small incisor.

ORANG.

Resemblances.—Straight line of teeth; large canine and diastema.

Differences.—Shortness of premolars; small size of last molar; difference in wear of canine; small incisor.

It thus seems to be apparent that the fossil jaw has most points of resemblance with the chimpanzee, and that when it differs from that species it has an ultra-human character. It now remains to consider to what fossil form the jaw presents any points of affinity, and we will first direct our attention to the Siwalik Primates.

As regards size alone, the only one of the jaws of Siwalik Primates represented in Plate XXIV of the first volume of the "Palæontological Memoirs" which could possibly have any affinity to our specimen, is that of *Semnopithecus subhimalayanus* (figs. 1 and 2); the teeth of that jaw, however, and of all the specimens on the same plate, are of the semnopithecine type, and have therefore no affinity to our fossil. The same remark of course applies to the teeth of *Macacus* represented in figs. 3 and 4 of the plate accompanying this paper.

One other tooth of a quadrumanous animal from the Siwaliks is, however, described and figured by Falconer on page 304 of the first volume of the "Palæontological Memoirs;" this specimen consists of the crown of the upper canine of a large ape allied to the orang; the specimen evidently belonged to a male individual, and is somewhat larger than the canine of the male orang. Our fossil jaw, which, as we have already seen, belonged to a female, has teeth somewhat larger than those of the female orang; there is therefore every probability that Falconer's canine and our new jaw belonged to the same species.

Turning, now, to the fossil quadrumanous animals of Europe, the only three genera with which I am acquainted which are likely to have any affinity to our specimens are *Mesopithecus*, *Pliopithecus*, and *Dryopithecus*.

Mesopithecus, from the Pikermi beds,[1] is of small size, and is regarded as being intermediate between *Hylobates* and *Semnopithecus*; the teeth are, however, distinctly of the semnopithecine type, and consequently quite different from those of our fossil.

Pliopithecus,[2] from the Miocene of France and Switzerland, is also of small size, and resembles *Hylobates* so closely, that it is referred by Professor Rutimeyer to that genus.

Dryopithecus,[3] from the Miocene of France, is an ape of larger size, which is, I believe, only known from the lower jaw and some limb-bones, and which from the small size of the canine and diastema is regarded as having an affinity to

[1] "Animaux fossiles et Geologie de l'Attique," Gaudry, Pl. I.

[2] Lartet: "Comptes Rendus," Vol. 3, p. 222, and plate. Heer: "Primæval World of Switzerland," Vol. II, p. 82, Pl. XI.

[3] Lartet: sup cit. Owen, "Palæontology," p. 383.

man. The antero-posterior extent of the second premolar, according to Professor Owen, is, however, greater than in the chimpanzee, and therefore still greater than in the Siwalik fossil; the latter, however, agrees with *Dryopithecus* in having narrow incisors.

Reviewing the whole of the foregoing facts, it does not appear that our fossil jaw agrees precisely with the jaw of any known living or fossil anthropoid ape, though it seems to make the nearest approach to that of the chimpanzee, and also shows some points of affinity with the jaws of man, *Dryopithecus*, and the orangs. The resemblance between the Siwalik jaw and that of the chimpanzee does not, however, appear to me to be so close as to warrant our classing the two under the same genus, because, with the very marked difference which occurs in the relative dimensions of the last premolars in the two jaws, there is every probability that equally well marked differences existed between the crania of the two animals. It must, however, be again borne in mind that the chimpanzee and the gorilla, which present such difference in the form of this tooth, are classed in the same genus.

Since I do not think that we are justified in referring the Siwalik jaw to any known genus, I propose to form for it the new generic name '*Palæopithecus*,' with the specific affix of '*sivalensis*.'

I can only hope that on some future occasion we may be fortunate enough to come across the cranium of this most interesting relic of the past, when we shall be able with some approach to certainty to assign to it its exact affinities, which with our present meagre specimens we can only vaguely guess at. We can only say that there lived in the Siwalik period of India, a huge anthropoid ape intermediate in size between the orang and the gorilla, the males and females of which were provided with canines exceeding in size the other teeth, and that those of the former bore about the same proportion to those of the latter as we find prevailing in the living anthropoid apes. Further, in the form of its teeth, this ape was nearest to the chimpanzee; but in the points in which it differed from that species, it shows great resemblances to the teeth of man.

I will conclude this notice with a few general considerations regarding the past and present distribution of the anthropoid apes. If this distribution in time and space be tabulated, as is done in the accompanying note,[1] it will, I think, be apparent that such living and fossil anthropoid apes as we are now acquainted with are merely a few from a large number of species which once existed on the earth.

	Miocene.	Pliocene.	Recent.
[1] *Troglodytes*	...	...	W. Africa.
Simia	...	...	Borneo and Sumatra.
Palæopithecus	...	N. India.	
Dryopithecus	W. Europe.		
Hylobates	...	...	Malaya, Assam, and China.
Pliopithecus (=*Hylobates* ?)	W. Europe.		

Further, it seems hardly to admit of doubt that three such closely allied genera as *Troglodytes*, *Palæopithecus*, and *Simia* must have had a common parentage and a common ancestral home. For three tropical or sub-tropical genera inhabiting respectively Western Africa, Northern India, and Sumatra and Borneo, the unknown common home may have possibly been situated in the Indian Ocean, being in fact the hypothetical sunken southern continent, whether it be called 'Lemuria,' 'Indo-Oceania,' or what not, to the former existence of which so many separate lines of evidence point. This vanished land was probably once the common home of the African and Indian ostriches,[1] which must have had a common centre of dispersion. Here also we may possibly look for the old home of the *Manis* of Siwalik and modern India, and of modern Africa.

If this hypothetical sunken southern continent[2] was the centre of dispersion of the anthropoid Primates, it is not improbable, nay rather it is almost certain, that numbers of species and genera must have lived and died, and finally become extinct, on that continent, and that only some of their descendants reached the borders of that continent—in other words, Africa, India, and Borneo. If this be so, it is probable that all records of some anthropoid Primates have long since, and for ever, been entirely removed from human cognizance, while it is possible that among these may have been forms nearer to man than any of those of which we have any records. On this supposition it is possible that we may never discover the "missing links." On the other hand, we have in the tropical countries which border the Indian Seas the probable periphery of this sunken continent, and it is among the unexplored tertiaries of these countries that we may yet hope to find fossil forms of *Primates*, which may tend to bridge the great gulf which now exists between the highest known ape and man. Of these countries, the geology of Africa and Sumatra and Borneo is virtually unknown. In India only a few scattered localities have hitherto yielded mammalian remains, and remains of Primates are of extremely rare occurrence in them. Thus, in the much-worked Siwaliks we only know of two specimens of the remains of anthropoid apes, which have been discovered at an interval of many years apart, among thousands of specimens obtained. There is, therefore, no reason to assume that other forms of anthropoid apes did not exist in that period. In Central and Southern India, with the exception of the little known Perim beds, we have no equivalents of the Siwaliks; and there is here therefore abundant room for older Primates to have existed without our having the least knowledge of them.

In the newer Nerbudda group scarcely any small fossils have been collected; and yet there is an absolute certainty that many forms of Primates

[1] STRUTHIO ASIATICUS, M.-Edwards, "Oiseaux Fossiles de la France," Vol. II, p. 587, and article in present number.

[2] Mr. Wallace ("Tropical Nature," p. 329) has come to the conclusion that "Lemuria" never existed, or that it at all events must have disappeared before the miocene. There appears to me, however, to be a great weight of evidence in favor of a former land connection between the continents of the old world, though this connection may very possibly have disappeared in comparatively early Tertiary times.

must have existed at that time, many of which were probably distinct from living species.

Our knowledge, therefore, of the tertiary faunas of the Tropics and Sub-Tropics is really extremely slight; and until this slight knowledge has been amplified by the fullest explanation of every tertiary rock stratum in Africa, India, and Malaya, no one is entitled to assert that man and the anthropoid apes had no common ancestor, because no such ancestor has hitherto been discovered; and even if such exploration were made without results, there remains the hypothetical sunken southern continent, with the disappearance of which may also have disappeared the "missing links."[1]

Finally, one other lesson is to be learnt from the Siwalik ape. We know that the living anthropoid apes dwell only in the deepest gloom and solitude of primeval forests, where vegetation grows luxuriously, and offers a constant supply of fruits throughout the year. From this we may probably infer that the Siwalik ape inhabited a similar forest-clad country, and that, consequently, the present Siwalik area of the Punjab was in parts at all events clothed with forests in which dwelt the *Palæopithecus*, instead of being, as now, a sun-scorched and somewhat desolate region. Evidence of the former existence of these forests is, as I have previously remarked,[2] afforded us by the occurrence of numbers of fossil tree-stems in various parts of the Siwaliks.

MACACUS SIVALENSIS, *nobis.*

In figs. 2 and 4 of the accompanying plate are represented the two fragmentary upper jaws of *Macacus sivalensis*, which were described by me on page 66 of the last volume of the "Records," and which, therefore, need no further notice on the present occasion.

RODENTIA.

RHIZOMYS SIVALENSIS, *nobis.*

The specimen drawn in fig. 3 of the same plate is a fragment of the left ramus of the mandible of the *Rhizomys* described by me at page 100 of the last volume of the "Records," and which I then considered to belong in all probability to a new species. The first molar has been broken away in the specimen but the second and third molars are in excellent preservation; the greater part of the incisor is seen on the inferior border.

PROBOSCIDIA.

DINOTHERIUM INDICUM, Falc.

A detached first lower true molar of a *Dinotherium* has been obtained through Mr. Blanford from the Laki Hills of Sind, which is larger than and of different shape from the corresponding tooth in the lower jaw of *Dinotherium*

[1] See an article on this subject in the Quarterly Journal of Science for October 1878.

[2] Rec. Geol. Surv. India, Vol. IX, p. 100.

pentapotamiæ from Sind, noticed at page 75 of the last volume of the "Records", and which agrees so exactly, as regards dimensions, with the base of the corresponding tooth in the lower jaw of *D. indicum* from Perim Island represented in fig. 6 of plate 35 of the "Fauna Antiqua Sivalensis," that I have considered it to belong to that species.

The tooth is considerably worn, and carries three equal sized transverse ridges, which show no sign of a median longitudinal division, which, with the bluntness of the ridges, shows that the tooth did not belong to a *Trilophodont Mastodon*. The tooth is relatively narrow in proportion to its length, which shows that it belongs to the lower jaw, while the greater elevation of the inner side of the ridges shows that it belonged to the left side. On the outer and posterior sides of the tooth there is a large thick cingulum.

I have given below the dimensions of this tooth, together with those of the corresponding tooth of *D. giganteum* in the large Eppelsheim cranium, and of the corresponding tooth in the above-mentioned jaw of *D. pentapotamiæ*:—

	New tooth.	*D. giganteum.*	*D. pentapotamiæ.*
Length of tooth	3·9	3·5	2·35
Width of 1st ridge	2·5	2·6	1·8
" of 2nd "	2·5	2·6	1·8
" of 3rd "	2·4	2·2	1·7

The tooth is slightly larger than the corresponding molar of *D. giganteum*, in which it agrees with Falconer's fragment, and is far too large to have belonged to *D. pentapotamiæ*; it is further distinguished from the same tooth in both those species by the presence of the large cingulum.

If now we turn to the description of the above-mentioned jaw of *D. indicum* on page 407 of the first volume of the "Palæontological Memoirs,"[1] we shall find that the dimensions of the base of the crown of the first true molar are as follows—length 4, width 2·8; these dimensions agreeing very closely with those of our new tooth. The latter further agrees with a fragmentary tooth of *D. indicum* from Perim Island, described by Dr. Falconer at page 397 of the first volume of the "Palæontological Memoirs," in the great thickness of the enamel, which in both measures 0·25 inch; in *D. pentapotamiæ* and *D. giganteum* the enamel is much thinner. Although, therefore, the perfect corresponding tooth of *D. indicum* is unknown, I think on the above grounds I am justified in refering the new tooth to that species. This identification is of great importance in connecting the horizon of the Perim Island and Sind rocks as I shall have occasion to note more fully below.

A portion of another tooth of a large *Dinotherium* has been received among a collection made by the late Dr. Verchere, which appears to have come from

[1] P. 397.

Dera Ghazi Khan, and which seems undoubtedly to belong to the same species. The specimen consists of the last ridge of a third upper molar of the left side, but very little worn. Its dimensions are given below, together with those of the second upper molar of *D. pentapotamiæ*, described at page 55 of the second fasciculus of the tenth series of the "Palæontologia Indica," and also with those of the same tooth of *D. giganteum* :—

	D. indicum.	*D. giganteum.*	*D. pentapotamiæ.*
Width of last ridge	3·7	3·4	2·3
Thickness of base of ridge	1·8	1·6	1·1

The new tooth differs from the figured specimen of *D. pentapotamiæ* in having no ledge on the hinder side of the last ridge, and in the ridge itself being somewhat less curved; it agrees with the other teeth of *D. indicum* in having very thick enamel, and being slightly larger than the corresponding tooth of *D. giganteum*; there is a tubercle on the inner side of the transverse valley.

New species of Dinotherium.

In addition to *Dinotherium indicum* and *D. pentapotamiæ*, we have now evidence of a third species of Indian species of the genus. The specimen from which this evidence is derived consists of a portion of the lower jaw, containing the two last molars, collected by Mr. Fedden in Sind. The jaw and teeth are much smaller than those of *D. pentapotamiæ*; the characteristic point of the jaw is, however, its cylindrical form, in which respect it differs from all other species of the genus.

Genus MASTODON.

Of the genus *Mastodon*, Mr. Theobald's last collection contains a great number of specimens of the jaws and teeth, some of which are of great interest, and add considerably to our knowledge of these animals. A few of the most interesting specimens are noticed here cursorily, as it will be a long time before I shall be able to describe them in detail.

Mastodon pandionis, Falc.

The first specimen in this collection which calls for especial notice is a portion of the mandible of a *Mastodon*, which cannot be referred to any of the previously known Siwalik species. The specimen comprises a portion of the horizontal ramus with two molars, and the symphysis of the mandible; the intermediate portion of the specimen was also discovered, but unfortunately crumbled to dust during its transit down country. The most noticeable portion of this jaw is the symphysis, of which the part now remaining has a length of 22 inches; this part is laterally compressed, and on its upper surface is excavated by a large groove upwards of 5 inches in depth at its proximal extremity.

The one complete tooth in this jaw carries four transverse ridges and a hind talon; its length is 8·5, and its width 3·7 inches; this tooth is the last true molar, and the jaw therefore belongs to a *Trilophodon*. The crown of the penultimate

molar is unfortunately broken away, but from the small size of its base, I imagine that it could only have carried three ridges. The last molar has a very deep longitudinal valley, which divides each transverse ridge into a distinct outer and inner column; large accessory columns are placed in the valleys, which are in consequence completely blocked. The disks of wear of the columns form irregular circles; the tooth has some resemblance to some varieties of the molars of *M. sivalensis*, in which the alternate arrangement of the columns is less pronounced than usual; the last molar of the latter has, however, five or six ridges. When complete, the distal extremity of the mandible must have been at least 30 inches in advance of the last molar.

There are no tusks in this specimen; among Mr. Theobald's collection, however, there is the distal extremity of an elongated mandibular symphysis of a species of *Mastodon*, which carries portions of two very large tusks. This mandibular rostrum cannot belong to any of the described species of Siwalik *Mastodon;* and as it agrees in form with the last specimen, I consider it probable that both belonged to the same species; the tusked jaw being that of a male, and the tuskless that of a female individual. The fragments of tusks remaining in the specimen are only some 10 inches in length; they are much compressed laterally, the transverse section being pear-shaped, having the thinner end upwards. The inferior border of the fragments is convex, and the superior border concave; the vertical diameter is 3·2 inches, and the transverse diameter at the thickest part 1·11 inches.

Another specimen of the mandible of a trilophodont *Mastodon* broken off at the symphysis, carries two molars, which are respectively the penultimate and last. The second of these teeth agrees precisely with the corresponding tooth of the last specimen of the mandible, but being less worn, is more suitable for description; the identity of these teeth shows that the two mandibles belonged to the same species. The penultimate tooth in the second mandible carries three ridges and a hind talon, which proves that the first jaw belongs to a *Trilophodon*. In these teeth each ridge is divided by a longitudinal channel into an inner and an outer column; each outer column gives off an accessory column from either side, which together project obliquely into and quite block the transverse valleys. The whole arrangement of the columns on the outer side form a zigzag arrangement; while the summit of each column wears into a circle.

Now, the only two known Indian trilophodons are *M. falconeri* and *M. pandionis;* the molars of the former I have not yet been able to describe. The penultimate lower molar of that species is, however, much larger than the same tooth in our new specimens, and has nearly open valleys, with distinct and clear ridges, whose summits wear into trefoils and not into circles. I shall hope shortly to be able to show by a figure the complete distinctness of these two teeth. The jaws of the two are further very different—that of *M. falconeri* being thick and rounded, while the present specimens are thin and flat.

Of *M. pandionis* a description of the penultimate upper molar will be found at page 124 of the first volume of the "Palæontological Memoirs of Dr. Fal-

coner"; if the description of that tooth be compared with that of the corresponding lower tooth noticed above, it will be seen that the two agree precisely, except that one is the reverse of the other, as is always the case in upper and lower molars. I have therefore no doubt but that these new jaws belong to *M. pandionis*, which was consequently a species provided with a long spatulate mandible, and of which the male carried inferior tusks.

The interest of this discovery of *M. pandionis* in the Siwaliks is very great; the other known teeth are said to have been obtained from the Deccan from deposits supposed by Falconer[1] to be of pliocene age; wherever they came from, it is now probable that they belong to the same period as that in which lived the other animals of the Siwalik fauna. In cataloguing the fossil *Proboscidia* in the Indian Museum, I have lately come across a last milk-molar of a trilophodont *Mastodon* from Perim Island which seems undoubtedly to belong to the same species.

In treating of *M. pandionis* at page 124 of the first volume of the "Palæontological Memoirs," Dr. Falconer remarks on the great similarity of the general plan of the teeth of *M. pandionis* and *M. angustidens*, the plan of the former being, however, rather the more complex of the two. It is interesting to observe how this similarity of plan in the structure of the teeth extends into as much as we know of the osteology of the two animals; thus the newly discovered specimens reveal to us that both the species were furnished with a long spatulate symphysis to the mandible, tuskless in the female, but in the male provided with a pair of relatively large and slightly curved tusks. From this similarity in structure we may, I think, infer that these two species of Mastodon were very closely related to one another, and that it is not impossible that at no relatively distant epoch they must have had a common parentage. One very important difference, however, exists in the structure of the teeth of the two species, which is that in *M. pandionis* (though this is not mentioned in Falconer's specimen) there is a large quantity of cement in the valleys, which is entirely wanting in the molars of *M. angustidens*.

MASTODON PERIMENSIS, Falc. & Caut.

Two very interesting points in relation to the dentition of this species are shewn among Mr. Theobald's last collection; one of them is, that this species, like *M. latidens*, was provided with an ultimate upper premolar, and the other that the species carried tusks in the mandible. The specimen proving the existence of an upper premolar consists of a portion of the left maxilla containing two teeth; the hinder of these teeth is 4½ inches in length, carries four transverse ridges, and small fore-and-aft talons; the anterior tooth has not yet come into wear, being only in germ, and having its masticating surface on a level with the base of the crown of the hinder tooth, which proves it to be a premolar, which has only just displaced the milk-molar which it has succeeded.

[1] Pal. Mem., Vol. II, table, p. 14.

The premolar is rounded, and carries two transverse ridges and two small talons. The larger tooth corresponds exactly in form with the first or antepenultimate molar of *M. perimensis* from Perim Island, represented on plate 9 of the first volume of the "Paleontological Memoirs of Dr. Falconer," and which is now in the Indian Museum. Mr. Theobald's specimen is, however, rather the smaller of the two. From the large size of the premolar in the new jaw, I think that that tooth must be the last, and that the tooth which it has replaced must consequently have been the last milk-molar; the second tooth will consequently be the first or antepenultimate true molar, and will correspond to the abovementioned specimen of Falconer's: the slight difference in size of the two specimens is very probably due to difference of sex.

I have already mentioned at page 71 of the last volume of the "Records" the discovery of a complete mandible of this species, and of the possible occurrence of lower tusks. Two specimens of the symphysis of the mandible of the same species in Mr. Theobald's last collection have now made it certain that certain individuals, probably males, were furnished with small mandibular tusks. Both the new specimens have been fractured, and exhibit sections of the tusks in their alveoli; these tusks were of small size, and show an oval cross-section, of which the vertical diameter in the middle of the symphysis is 1·6 inches, and the transverse diameter 1·3.

PERISSODACTYLA.

ACEROTHERIUM PERIMENSE, Falc. & Caut.

The discovery of a nearly complete cranium of this species in the Siwaliks of the Punjab by Mr. Theobald is of great interest, as only very fragmentary remains of the species have hitherto been known. The new cranium is further interesting, as showing the accuracy of Falconer's opinion (formed on the evidence of a few generally imperfect teeth), that the Perim Island Rhinoceros was hornless, and belonged to the genus *Acerotherium*.

The cranium, with the exception of a few minor injuries, only lacks the extremity of the nasals, and maxillæ and premaxillæ, together with the greater part of the zygomatic arches, to be complete, and is generally in a very excellent state of preservation. As I shall hope on a future occasion to give a figure and a more detailed description of this cranium, it will only be noticed very shortly here.

The cranium is that of a fully adult animal, the permanent molars being greatly worn down, and the cranial sutures mostly obliterated; it is also of huge dimensions. It is at once distinguished from the three species of true Siwalik Rhinoceros, of which figures of the cranium are given in the "Fauna Antiqua Sivalensis" by its straight profile, in place of the highly curved profile which characterizes the other species. It is further distinguished by the very small size of the nasals: these bones are unfortunately broken off near their base, but sufficient of them remains to show that they formed merely a short conical pro-

jection, having no resemblance to the broad and curved bones which occur in the other species. The transverse diameter of the base of these bones in the new cranium is only 3·3 inches, whereas in the smaller crania of *R. sivalensis* and *R. palæindicus* it is 5 and about 4·8 inches respectively, and in the large *R. platyrhinus* is upwards of 6·5 inches. Again, the base of the nasals in the new cranium is perfectly smooth even on the upper surface, shewing that there was no nasal horn, such as exists in the other species; the frontals are also perfectly smooth, and shew no signs of having ever carried a horn. The cranium, therefore, is truly that of an *Acerotherium*, and as such quite distinct from the other Siwalik species of Rhinoceros.

Together with this cranium, Mr. Theobald has sent the less worn upper dentition of another individual of the same species, which is in a better state for comparison than the more worn dentition of the cranium. The antepenultimate upper premolar in both these specimens agrees exactly with the corresponding tooth represented in fig. 15 of plate 75 of the "Fauna Antiqua Sivalensis," which is the type of *A. perimense;* the true molars in Mr. Theobald's specimens also agree with the fragmentary molars of the same species represented on the same plate; the new cranium may, therefore, be safely referred to *A. perimense.*

This being so, the complete dentition of this species now enables me to correct a very serious error into which I had fallen, and through which I had been led to form a new species of Siwalik Rhinoceros, (*R. planidens*), though working with imperfect materials.

If we turn to figures 7 and 8 of the second part of the tenth series of the "Palæontologia Indica," it will be found that I figured two imperfect upper molars of a Rhinoceros, which I considered to be different from the corresponding teeth of any other species, and which I accordingly referred to a new species under the name of *R. planidens.* Subsequently several complete upper molars, and a considerable portion of a mandible, together with an upper incisor, all of large size, were obtained by Mr. Theobald, and were referred to under the same specific name at page 96 of the last volume of the "Records."

Now, the true molars in Mr. Theobald's two latest specimens agree precisely with the above-mentioned upper molars, and clearly belong to the same species. It is therefore clear that the new species *R. planidens* must be merged in *A. perimense.*

In figure 5 of Plate VI of the same volume of the "Palæontologia Indica" I figured two teeth of *A. perimense,* which I considered to be the last premolar and the first true molar, because, as will be seen by the figure, the second of these two teeth is the most worn. Considering this latter tooth to be a true molar, it was apparent that the true molar referred to *R. planidens* could not belong to *A. perimense.* A comparison of the two teeth in question with the dentition of Mr. Theobald's specimens shows, however, that these teeth are really the first and second premolars, and that their relative rate of wear must be an abnormality. I may add that I ought to have known that these two teeth must

have been the two middle premolars, because no such discrepancy in size occurs between the last premolar and first true molar as occurs between these two teeth, while the smaller tooth is of too small dimensions to have been the last true molar. I may add that the tooth represented on Plate VI, figure 2 of the above referred to volume of the "Palæontologia Indica," as the first true molar of *A. perimense*, is really the penultimate premolar; and that the unnamed tooth from Sind, represented on figure 6 of the same plate, seems to be the antepenultimate upper premolar of the same species.

On a future occasion I shall hope to be able to give figures of the almost complete upper and lower dentition of the present species; and I cannot but regret that I have previously published figures of such very imperfect specimens. It is interesting to observe that *A. perimense* agreed with the European *A. incisivum*, in being hornless, and in being furnished with a single pair of very large upper and lower incisors, clearly showing that the absence of one weapon of offence or defence is compensated for by the greater development of another.

I may here mention that we seem to be gradually obtaining evidence that the mammalian fauna of the Punjab and Sind forms a connecting link between the fauna of Perim Island on the one hand and of the more eastern Siwaliks on the other. Thus, as will be gathered from a perusal of this and my previous papers in the Records, we have in the Siwaliks of the Punjab and Sind the following Perim Island mammals, which were not known to Falconer from the more easterly Siwaliks, *viz.* :—

Dinotherium indicum. P.; I. P. S.
Mastodon pandionis. P.; I. P. Deccan (?)
Mastodon perimensis. P.; I. P. S. (?)
Hyotherium sindiense. P.; I. S.
Acerotherium perimense. P.; I. P. S. (?)
Hippotherium theobaldi. P.; I. P.

All these mammals belong to old forms, and seem to indicate that the Perim Island deposits and the zone in which they occur in the Punjab (position unknown) are low down in the series and correspond to the older Sind Siwaliks.

Distribution of genera of Siwalik Mammals.

Since the publication of my paper on the "Fossil Mammalian Fauna of India and Burma," [1] several new genera have been added to these fauna, and the distribution of the previously known genera has been further elucidated. I have therefore compiled the following table of the distribution of the mammalian genera in the Siwalik and the other tertiaries below the Nerbudda group, which must be taken as superseding the tables given on pages 90-92 of my above quoted memoir.

[1] Rec. Geol. Surv. Ind., Vol. IX, pt. III.

Table of distribution in India of Siwalik Mammalian Genera.

Order.	Genus.	Burma.	Sylhet.	Country east of Jhelam R.	Punjab west of Jhelam R.	Sind.	Perim I.
PRIMATES ...	Palæopithecus ...	...	...	×	×	...	...
	Semnopithecus ...	...	...	×	...	...	...
	Macacus	...	...	×	×	...	...
PROBOSCIDIA ...	Dinotherium... ...	...	...	...	×	×	×
	Mastodon	×	...	×	×	×	×
	Stegodon	×	×	×	?	...	...
	Loxodon	...	...	×	...	...	...
	Euelephas	...	...	×	...	...	...
UNGULATA ...	Sus	...	×	×	×	×	×
Artiodactyla ...	Hippohyus	...	...	×	×	...	×
	Tetraconodon ...	...	...	×	×	...	...
	Hippopotamus ...	×	...	×	?	...	...
	Sanitherium... ...	...	...	...	×	...	...
	Listriodon	...	...	...	×	?	...
	Hyotherium... ..	...	...	...	...	×	×
	Anthracotherium ...	...	×	...	×	×	...
	Hemimeryx... ...	...	...	...	...	×	...
	Sivameryx	...	...	...	...	×	...
	Hyopotamus... ...	..	...	...	...	×	...
	Chœromeryx ...	...	×	...	...	...	...
	Merycopotamus ...	×	...	×	×	...	...
	Chalicotherium ...	...	...	×	...	×	...
	Camelus	...	...	×	...	...	...
	Sivatherium	...	...	×	...	...	...
	Hydaspitherium ...	...	...	...	×	...	...
	Vishnutherium ...	×	...	...	?	...	...
	Bramatherium ...	...	...	...	...	...	×
	Camelopardalis ...	...	...	×	×	...	×
	Antilope	...	..	×	×	...	×

Order.	Genus.	Burma	Sylhet.	Country east of Jhelam R	Punjab west of Jhelam R.	Sind.	Perim I.
Artiodactyla — contd.	Bos	?	...	×	...	...	...
	Hemibos	...	...	×	?	...	...
	Amphibos	...	...	×	?	...	...
	Peribos	...	...	×	...		...
	Bubalus	...	...	×	...	...	...
	Bison	...	...	×	...	...	...
	Capra	...	...	×	×	...	×
	Dorcatherium ...	...	...	×	×	...	...
	Cervus	?	×	×	×	...	...
Perissodactyla ...	Acerotherium ...	?	...	?	×	×	×
	Rhinoceros	×	...	×	×	×	?
	Hippotherium ...	...	..	×	×	...	×
	Equus	?	...	×	...	...	...
CARNIVORA ...	Hyænarctos	...	...	×	×	?	...
	Ursus	?	...	×	...	...	...
	Mellivora	...	...	×	×	...	...
	Meles	...	...	...	×	...	...
	Amphicyon	...	...	×	×	×	...
	Enhydriodon ...	...	.	×	..	...	...
	Lutra	...	...	×	×	...	...
	Canis	...	...	×	?	...	...
	Ictitherium	...	...	...	×	...	...
	Hyæna	...	...	×	×	...	...
	Machairodus... ...	...	...	×	...	...	...
	Felis	...	...	×	×	...	...
	Pseudælurus... ...	...	...	...	×	..	...
RODENTIA ...	Hystrix	...	...	×	×	...	...
	Rhizomys	...	...	?	×	...	...
	Mus	...	...	×	...	...	...
EDENTATA ...	Manis	...	...	...	...	×	...

In the above table there are a few points which call for short notice. In the first place, the number of specimens collected from Sylhet is so small, that no inference as to the absence of genera from the formations of that district can be drawn from their absence in the table: to a less degree the same remark applies to Burma and Perim Island. Again, in the three columns headed respectively Country east of Jhelam R.," "Punjab, west of Jhelam R.," and "Sind," I do not wish to lay any great stress on the absence in any of these columns of any of the rarer genera, such as *Sanitherium, Amphicyon,* or *Lutra,* as indicating their absence from the formations under those columns. On the other hand, the presence or absence in any of these columns of any of the common genera, such as *Euelephas, Merycopotamus, Bos* or *Equus*, is of great weight, and is to be considered in many cases as a fact in distribution.

We may notice in Sind the complete absence of the following common Siwalik genera, *viz., Stegodon, Loxodon, Euelephas, Hippopotamus, Merycopotamus, Camelus, Camelopardalis, Bos, Bison,* and *Equus;* and we may further note that most of these genera are modern forms, and that most of them are not found in the country to the west of the river Jhelam, but that they occur commonly enough in the country to the east of that river. Again the genera *Dinotherium, Listriodon, Hyotherium,* various Suina, *Hyopotamus,* and *Acerotherium,* are of fairly common occurrence in Sind and the Punjab, and do not, I believe, occur in the country to the east of the Jhelam, with the exception perhaps of *Acerotherium,* which has been found a little to the east of that river. Again the genus *Equus,* which is extremely common in the Siwalik country of Falconer, is unknown in the Western Punjab, and is there replaced by *Hippotherium,* of which genus at least two species occur there very commonly, of which one *(H. artilopinum)* occurs in the more eastern country, while the other *(H. theobaldi)* is only known from the Western Punjab and Perim.[1]

The table in fact shows that the more modern genera are mainly characteristic of the country to the east of the Jhelam, while the Punjab, Sind, and Perim Island are characterized by an older facies of genera,—the greater number of old genera occurring in Sind. The Sind fauna is consequently to be regarded as the oldest of the Siwalik group, that of the Punjab and Perim Island probably the next in age, and the Siwaliks of the Dehra Dún and neighbouring country as the newest of all. I wish, however, to add that although I think the difference in the mammalian faunas of the different districts under discussion are due in great measure to differences in relative age, yet that it is probably that many of the genera, such as those of the *Sivatheridæ,* were strictly contemporaneous, and were limited in their geographical range.

[1] In Falconer's catalogue of the *Vertebrata* in the collection of the Asiatic Society of Bengal the molars of this species are referred to *Equus.* I believe I have evidence of the existence of four species of the genus in the Púnjab.

DESCRIPTION OF PLATE.

Fig. 1. PALÆOPITHECUS SIVALENSIS, nobis.
Lateral view of right maxilla.

„ 2. MACACUS SIVALENSIS, nobis; palatal view of right maxilla.

„ 3. RHIZOMYS SIVALENSIS, nobis; palatal view of left ramus of mandible.

„ 4. MACACUS SIVALENSIS, nobis; palatal view of left maxilla.

„ 5. PALÆOPITHECUS SIVALENSIS; palatal view of specimen represented in fig. 1.

Fig. 3 twice the natural size; the rest natural size. The two sides of the maxilla represented in fig. 5 have not been placed quite symmetrically. The perfect tooth on the left side of the figure should be opposite the decayed tooth on the right side.

NOTES ON SOME SIWALIK BIRDS, *by* R. LYDEKKER, B. A., *Geological Survey of India.*

INTRODUCTION.

In the Siwaliks, as in many other ossiferous formations, the fossil remains of birds are of extremely rare occurrence, and such bones as do occur are generally, owing to their delicate structure, merely fragments of the stouter extremities. Except in formations like the lithographic slates of Solenhofen, the skull of birds are scarcely ever preserved as fossils, and none have as yet been obtained from the Siwaliks. From time to time, however, a few fragments of bird-bones have been obtained from these deposits, and these are of extreme interest, as being the only evidence we have at present of the existence of an avian fauna in the Siwaliks. Some of these bones were collected by Dr. Falconer, and were deposited by him in the British Museum, figures being given of them on Plate R of the unpublished plates of the "Fauna Antiqua Sivalensis."[1] On the evidence of these bones M. A. Milne-Edwards[2] established two species of extinct Siwalik birds, namely, *Struthio asiaticus* and *Argala falconeri*. From the evidence of another bone which is not figured in the "Fauna Sivalensis," the same writer considered, that a bird allied to *Phaëton* must have lived with the Siwalik fauna.

Among the vast collection of mammalian and reptilian bones obtained by Mr. Theobald from the Siwaliks, there are a few fragmentary bird bones; and these together with the bones collected by Dr. Falconer, form mainly the subject of the following short notes. These notes are not intended as an accurate description of the bones, because I wish to defer that description in the hope that I may hereafter obtain more complete materials. Some of the bones are, however, of such interest, that I have thought it well to bring their existence into notice, without deferring them to the indefinite period when I shall be enabled to give figures of them.

[1] Photographic copies of these plates can now be obtained at the British Museum.

[2] Oiseaux fossiles de la France, Vols. I, p. 449, II, p. 587.

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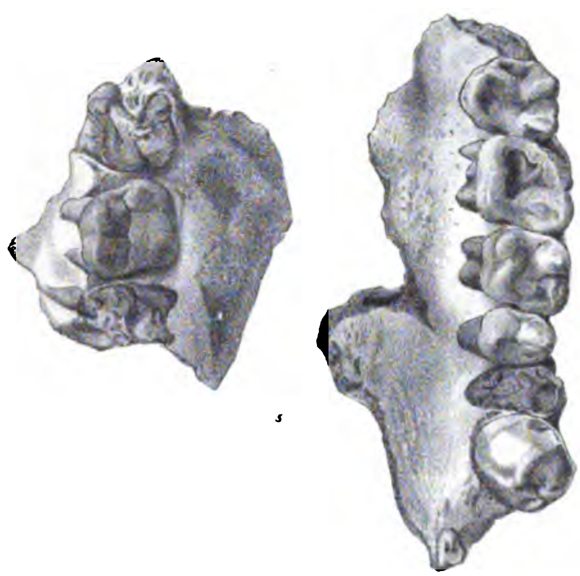

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FOSSIL STRUTHIOIDS.

With regard to *Struthio asiaticus* of M. Milne-Edwards, it appears that this species was formed on the evidence of the phalange, and of the distal extremity of the tibio-tarsus, which are represented in figs. 2 and 15 of the above-quoted plate of the "Fauna Antiqua Sivalensis." In noticing these species, M. Milne-Edwards (*loc. cit.*) remarks: "*L'une des espèces les plus remarquables appartenait au groupe des Brévipennes et se rapprochait beaucoup de l'Autruche d'Afrique par la conformation de son pied, qui ne portait que deux doigts.*" I am rather at a loss to discover how M. Milne-Edwards determined that his Siwalik ostrich had but two toes, because, as I have said, the only struthioid bones figured in the "Fauna Antiqua Sivalensis" are the distal extremity of the tibio-tarsus and a phalange. The first bone would, as far as I am aware, give no indication of the number of toes, and the second, which appears to belong to a median digit, is symmetrical in itself, and might, as far as I can see, belong to either a two- or a three-toed bird. It is, however, possible that M. Milne-Edwards may have seen a specimen of the tarso-metatarsus of this struthioid which would of course settle the question. In any case it is probable that such an authority on the subject as M. Milne-Edwards would not have made such a positive assertion without good grounds; and I therefore adopt his *dictum*, that the bird to which the two above-mentioned bones belonged was a two-toed ostrich.

I now come to four bones of a large species of struthioid, collected by Mr. Theobald in the Western Punjab. These bones comprise two specimens of the first and second phalanges of the outermost digit[1] of a three-toed struthioid bird; one pair of these bones is somewhat larger than the other pair. I will not describe these bones on the present occasion, but will content myself with saying that as regards form, they agree almost precisely in form with the corresponding bones of *Dromæus novæ-hollandiæ.*

The dimensions of the four fossil bones and the two corresponding bones of *D. novæ-hollandiæ* are as follows, in inches:—

	Large fossil.	Small fossil.	*Dromæus novæ-hollandiæ.*
Length of first phalange	2·4	2·3	1·8
Antero-posterior diameter of superior surface of ditto ...	1·36	1·25	0·75
Transverse ditto	1·3	1·2	0·7
Antero-posterior ditto inferior ditto	0·9	0·7	0·46
Transverse ditto	1·0	0·8	0·6
Length of second phalange	1·5	1·3	0·8
Antero-posterior diameter of superior surface of ditto ...	1·1	0·95	0·55
Transverse ditto	1·3	1·1	0·62
Antero-posterior ditto inferior ditto	0·7	0·65	0·45
Transverse ditto	1·3	1·1	0·54

[1] Corresponding to the fourth of the typical series.

It will be seen from the foregoing measurements that the fossil and recent bones bear the same relative proportions, and that the larger fossils are almost exactly double the size of the recent bones. The difference in the size of the fossils does not appear to be greater than that which might occur in different individuals of the same species. There are some very slight minor differences between the fossil bones and those of *Dromæus novæ-hollandiæ*, but they do not appear to me to be more than of specific value; and I think that the fossils should undoubtedly be referred to that genus.

It may be well to observe, that the outermost digit of *Struthio* has its phalangeal bones of a much more slender type than those of *Dromæus*, and each bone is more nearly symmetrical in itself than in the latter genus. The stout and obliquely shaped fossil bones cannot therefore belong to *Struthio*.

Had it not been that M. Milne-Edwards had referred the struthious Siwalik bones in the British Museum to the two-toed genus *Struthio*, I should have not improbably referred all the bones to one species. The tibio-tarsus of *Struthio asiaticus* is, however, rather small for the fossil phalanges. For the three-toed Siwalik struthioid bird I propose the name of *Dromæus sivalensis*. If it should turn out eventually that M. Milne-Edwards was erroneous in referring the struthioid tibio-tarsus to the genus *Struthio*, and that that bone really belongs to a three-toed species, then it may possibly belong to *Dromæus sivalensis*. Irrespective of this question, however, the new fossil bones afford us indisputable evidence of the former existence in India of an emeu of double the size of the existing emeu of New Holland, and which must have rivalled in size some of the gigantic fossil three-toed wingless birds of New Zealand.

If we accept M. Milne-Edwards' *Struthio asiaticus*, it is clear that the ostriches of Africa and the emeus of Australia once had a common home on the plains of India, and it is possibly from this common home that they have gradually spread, till they are now isolated from one another on opposite sides of the globe.

The living faunas of India and of the Australian region are almost totally distinct; but there are a few indications in Celebes and some of the neighbouring islands of there having been a former communication between the African Oriental, and Australian faunas; and it is probable that the same means of communication afford a passage for the *Struthionidæ*. Mr. Wallace,[1] in explanation of the supposed communication, suggests that a large tract of land formerly extended from Australia in a north-westerly direction to Asia, and that this old land was probably the home of the ancestors of *Sus*, *Babirusa*, *Phacochœrus*, *Anoa*, *Bubalus*, *Cynopithecus*, *Cynocephalus*, and *Macacus*, to which we may now probably add *Dromæus* and *Struthio*.

Since the emeus and cassowaries are not found fossil in Australia or New Guinea, while numerous fossil species of marsupials occur throughout these islands, and since struthioids are known to have existed in the older pliocene (or

[1] Geographical distribution of Animals, Vol. I, p. 437.

upper miocene) in Asia, while the marsupials (with the exception of the *Didelphidæ*) have not been known out of Australasia since the Eocene period, it is not impossible that the struthioid birds are a much later introduction into Australasia than the marsupials. At page 340 of "Tropical Nature," Mr. Wallace says that Australia was isolated during the whole of the tertiary period, and on the next page that it has not improbably been isolated since the oolitic period. If I am right in referring the fossil Siwalik bird-bones to *Dromæus* (and they are certainly closely allied) we have indications of a much later connection between India and Australia.

New Wader.

The next fossil bird-bones I wish to notice are an associated sternum and an incomplete tibio-tarsus of a gigantic carinate bird, which probably belonged to the order Grallatores; though it presents certain peculiarities which appear to distinguish it from all other living birds. This sternum and tibia were in the collection of the Asiatic Society of Bengal, and were marked in Dr. Falconer's handwriting as having been obtained from the Siwaliks, though no locality is mentioned. The sternum has a bold convex carina, and has a considerable general resemblance to the sternum of *Argala* (*Leptoptilus*); the notch on either side of the xiphi-sternum is, however, much deeper and larger, and the xiphi-sternum itself larger and longer. The sternum is moreover more expanded laterally than in *Argala*. The peculiarity of this sternum, however, is that the distal half of the furculum, which alone remains, is completely anchylosed to the superior border of the sternum, so that no trace of division is visible. Behind this anchylosed furculum are the long coracoidal grooves, which are placed much more backwards than is usually the case in birds. I do not know of any instance among living birds of such complete anchylosis of the sternum and clavicles, such anchylosis being usually confined to the hypocleidium of the furculum and the manubrium sterni. The fossil sternum is of considerably larger size than that of *Argala indica*, but from its general form seems clearly to have belonged to a bird allied to that genus. The tibio-tarsus which was associated into the sternum lacks its distal extremity (astragalus), as well as some portion of its proximal extremity.

The fibula is anchylosed to the upper half of the tibia, which shows that the bones do not belong to a struthioid, in which the tibia and fibula are distinct. The bone has the general shape of the tibia of *Argala*, but is flatter superiorly, and, in place of being slender, is stout and strong like the tibia of the ostrich. The length of the imperfect tibia is about 14 inches, while its transverse diameter superiorly is 1·8 inches, and its antero-posterior diameter 1·2 inches.

As regards size, our tibia has a great resemblance to the gigantic *Gastornie parisiensis*[1] of the French eocene, which is only known by its femur and tibia, and which seems to have characters common to the Grallatores and Natatores. The tibia of *Gastornis*, however, expands inferiorly, whereas the Indian bone contracts: there is also a great hollow in the former on the anterior surface above

[1] Oiseaux fossiles de la France, Atlas, Vol. II, pl. 29.

the condyles, which does not occur in the latter. In *Gastornis* the tendon of the *tibialis anticus* muscle passes through a distinct bony arch, which I think does not exist in the Indian fossil. Again, the Indian tibia has the fibula anchylosed to it for half its length, which is not the case in *Gastornis*. I am not aware of any other living or fossil bird (except the *Ratidæ*), which has a tibia approaching in size to that of our fossil.

These two bones indicate the former existence of a carinate bird, probably allied to the adjutant, but which in stoutness and length of limb was intermediate in size between the ostrich and the emeu. I propose to call this bird *Megaloscelornis sivalensis*[1]; the remains I hope to describe more fully on a subsequent occasion.

Argala falconeri, M.-Edwards.

The remains of *Argala falconeri* in the British Museum, according to M. Milne-Edwards (*loc. cit.*), consist of the proximal and distal extremities of a tarso-metatarsus, and two specimens of the distal extremity of the tibio-tarsus. Two of the bones indicate a bird larger than *Argala indica* (*Leptoptilus argala*), while the other two are of somewhat smaller size. In the Indian Museum we have three bones belonging to *Argala falconeri*, all of which were collected by Mr. Theobald in the Punjab: these bones comprise a very late cervical vertebra,[2] the distal extremity of a tibio-tarsus, and the first phalange of the outermost digit. The first two of these bones are of exactly the same size as the corresponding bones of *A. indica*, while the third is slightly smaller: as regards form all appear to me to be indistinguishable from the corresponding bones of the living species. Since some of M. Milne-Edwards' specimens are of somewhat larger size than the living adjutant, it is evident that the Siwalik adjutant attained a somewhat greater size than the living species; but as the bones of the two are indistinguishable in form, it appears to me to be very doubtful whether we have as yet any good evidence as to the specific distinctness of the living and fossil forms.

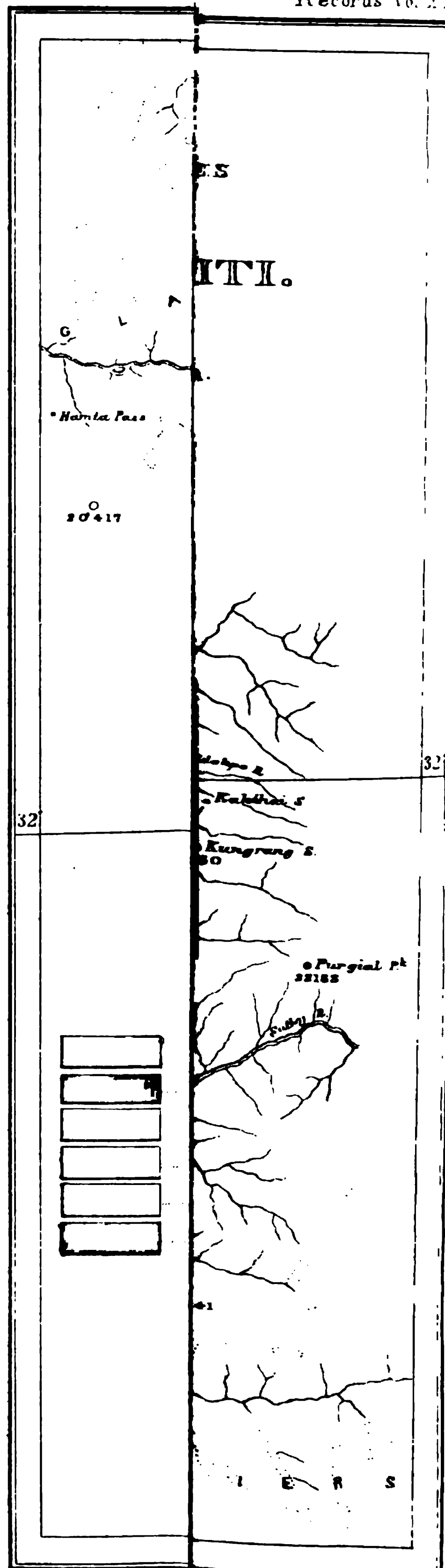
CONCLUSION.

Besides the above-described bones, there are in the Indian Museum a cervical vertebra and a tibio-tarsus of birds about the size of the common fowl, but whose affinities I have not yet determined.

There is also the distal extremity of the femur of a large unknown bird figured in the "Fauna Antiqua Sivalensis," as well as several fragments of bones of smaller birds. In the collection of the British Museum there is the distal extremity of the humerus of a large bird, which was recently discovered among some Siwalik specimens by Mr. Davis, who showed it to me; but I had then no opportunity of determining to what bird it belonged. It will be noticed that among these Siwalik bird-remains, those of *Argala falconeri* are the most common, and that the great majority of the known bones belonged to birds of large size.

[1] μέγας-αλος, σκέλος, ὄρνις.

[2] Rec. Geol. Surv. India, Vol. IX, p. 104.


ITI.
Hamta Pass
20417
32
Kungrang S.
Purgial Pk
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This, I think, can only be accounted for by the larger bones being, firstly, more likely to escape destruction, and secondly, being more likely to be obtained by collectors. We are not therefore, from the paucity of small bird-bones, to argue that the smaller birds were not fully represented in the Siwalik fauna, any more than in the case of the small mammals, of which the remains are likewise extremely rare. Since birds, as a rule, are of far inferior size to mammals, it is only natural to expect that the discovered fossil bones of the former should only present a very small percentage of those of the latter.

With regard to the Siwalik tarso-metatarsus stated by M. Milne-Edwards to indicate a bird closely allied to the living Tropic birds (*Phaëton*), it seems incredible that a bird of that essentially oceanic genus could have lived in the land-locked Siwalik country. The difficulty may perhaps be got over by calling in question the authenticity of the locality of the bone, of which there seems no certain history.

NOTES OF A TOUR THROUGH HANGRANG AND SPITI, *by* COLONEL C. A. MCMAHON.

Circumstances over which I had no control delayed my departure from Simla so long, that the time at my disposal was only sufficient to enable me to make road-side observations by the way. I could only devote one halt to explorations off the road.

In my last paper (Rec. Geol. Surv., X, p. 204) I described the rocks of the Upper Sutlej as far as Jangi, and I now proceed to describe the section from that place to Spiti, *viâ* the Ruhang and Hangrang passes.

The dip of the schists and central gneiss between Pangi and Jangi varies from north-east to east-north-east. Between these places, as described in my last paper, frequent intrusions of granite culminate in an eruption on a grand scale; the granite constituting the core of the Gongra ridge, and extending in a north-westerly direction from near the confluence of the Todoong Gar river with the Sutlej, to Lepi. Whether it extends beyond Lepi I do not know. The rocks fringing this central granitic core, and forming the minor ridges of the Gongra range, are mica schists. On leaving Jangi (elevation 8,850 feet)[1] the dip is at first flat, but as Lepi (elevation 8,880 feet) is neared, a west-south-west dip is set up. Between Lepi and the top of the Ruhang pass (elevation 14,354 feet, T. S.) the dip varies from north-north-east to north-west. The rocks, which at first are silicious and micaceous schists, gradually get more and more slaty, and finally pass into unmitigated slates with a grey streak.

Whether there is a gradual transition from metamorphic crystalline rocks to clay slates—the one gradually passing into the other—or whether the transition is merely apparent, I cannot positively state. It would require, I think, a careful detailed survey of the ground to decide the question definitely. It is impos-

[1] The elevations given are generally those shown by my aneroid barometer: when the trigonometrical survey elevations are given, the letters T. S. are affixed.

sible for a Himalayan traveller, with a long and toilsome march before him, to crack *every* piece of rock he sees, and scrutinize it minutely; and when rocks on their weathered surface give no outward indication of a change, it would be quite possible, I imagine, to miss the border line between slaty micaceous or slaty silicious schists on the one side, and micaceous or silicious slates on the other. The difficulty is increased not only by the fact that some metamorphic rocks in this area closely resemble in external appearance the sandstones and slates of the palæozoic series in contact with them, but also from the circumstance that both series have been alike affected by comparatively recent disturbances.

I have no note of any granite veins, and I feel sure I did not see any in the schists at Lepi. I see no reason to suppose that the intrusion of the Gongra granite (which I believe to be albite granite) occurred at a later period than the albite granite of other sections; and I do not, therefore, think that the metamorphism of the schists at Lepi can be explained by referring it to the rise of the granite.

At the top of the Ruhang pass the dip changes to south-south-west, and the angle of dip is high all the way down to Sungnam (elevation 9,520 feet). The rocks resemble the slates and fine sandstones of the Simla slate series.

At Sungnam, the slates, which are here nearly perpendicular (dip extremely high to west-by-south), are of a light grey color; but on the way up the Hangrang pass they get darker in color, and become like the Simla slate beds that so much resemble some of the nummulitic clays. At an elevation of 10,150 feet, the northerly dip is recovered by a sharp and fractured anticlinal, along which some of the beds above, dipping north-east, seem to have been pushed over the beds on the south-west side of the anticlinal.

At an elevation of 11,050 feet, the slates terminate suddenly, their junction with the rocks above them being masked by a side stream, running down from the top of the Hangrang pass. On the other side of this stream, pink limestone appears, in beds of from $1\frac{1}{2}$ to $2\frac{1}{2}$ feet in thickness. There are probably from 300 to 400 feet of them.

When first seen the pink limestones apparently dip north-north-west, but this rapidly subsides into a north-east-by-north dip. These beds are overlaid conformably by purple calcareous indurated clays that break under the hammer into lumps, and not into slaty slices. Over these is a small outcrop of a slate with a dark streak, which is overlaid, at an elevation of 12,000 feet, by a thin bed of dark-blue limestone. Then follow, in the ascending order, dark slates that break into acicular fragments. They reminded me so much of the argillaceous beds exposed on the eastern side of the Krol mountain[1] that it needed the test of acid to satisfy me that they were not calcareous. At an elevation of 12,300 feet these slates give place to dark-blue compact limestones, for the most part in beds of half a foot to two feet in thickness, and they continue up to the top of the pass (elevation 14,530 feet). A bed of greenstone occurs in them.

[1] Mem. G. S. I., Vol. III, pt. 2, p. 24.

Judging from the talus, I am under the impression that the rocks on the south-east side of the pass, namely, in the direction of the Thagiriga trigonometrical station, consist of slates faulted against the limestones; but I had no time to scale these cliffs to examine them. On the north-west side of the pass, and down to Hango (elevation 11,500 feet), the limestones continue; the north-easterly dip changes near the summit of the pass to a low west-north-west dip, producing, when the beds are viewed from below, an appearance of unconformity.

On the descent, at an elevation of 13,400 feet, clay slates re-appear, dipping south-west. From this point, owing to great contortion, the limestones and slates alternate several times, being sometimes perpendicular, at others dipping south-south-west. Near the bottom of the descent, a compact quartzite becomes prominent, sometimes perpendicular, sometimes dipping south-west-by-south, In color it varies from a bluish to a pinkish-white. Close to Hango, as another result of contortion, the thin-bedded limestones and slates re-appear, having an extremely high (nearly perpendicular) north-east dip.

The quartzites above described and the thin-bedded limestones at the top of the pass belong, I apprehend, to the Krol formation. I doubt if hand specimens could be distinguished from those taken from the Krol mountain itself. Most of the beds weather a dark blue, but some brown. The rock abounds in white calcite markings, similar to those so common in typical Krol rocks. The purple calcareous clays I have described as occurring on the south side of the pass reminded me of the purplish-red, sometimes calcareous clays of the Krol and Boj.

Proceeding onwards towards Leo on the Spiti river, the first rock seen on leaving Hango, and which dips north-east, is a highly silicious white limestone (weathering white) with a faint shade of green in it, due apparently to the presence of a little chlorite. On the weathered surface I saw what looked like a cast of *Nautilus spitiensis*, only about half the size of that figured in Plate IV, Memoirs vol. V, as one of the Lilang fossils. It seemed to vanish into nothing when examined with the aid of a lens, and broke into pieces on the first application of the hammer, leaving me in a painful state of doubt whether I had seen a real fossil or not.

The limestone just described is overlaid by a hard silicious dull pinkish-white limestone that weathers a dull red-brown. It might easily be taken for a quartzite, but it effervesces slightly with acid (strongly when powdered), and a qualitative analysis of it shows that it contains a good deal of lime and some magnesia. A thin slate is intercalated with these limestones. There are some hundreds of feet of these rocks, but I cannot say exactly how thick they are, as the hill side is obscured by talus for some miles. The reddish-weathering limestone appeared, from blocks that had fallen down, to be overlaid by a bluish-white quartzite.

As I journeyed onwards the north-east dip appeared to flatten and then to change temporarily to east-south-east, the change of dip bringing down to the road dark-blue limestones resembling those at the top of the Hangrang pass.

The white limestones at Hango are, I apprehend, the same rocks as the pink limestones on the south side of the pass.

Further on, at a point where the road, having rounded a spur, winds into the mountain side, slates re-appeared dipping west. As the silicious limestones did not crop out between the blue limestones and the slates, I presume they were hidden by the talus, which, at the level of the road, is very abundant along this section. As the crystalline series was neared I came to a pale bluish-white slate weathering a bright yellowish ochre color in irregular patches. Associated with the latter was a thin bed of dark slate, in some places as black as coal.

From these rocks I passed by a sudden transition to the crystalline series. The change takes place just where the road from Hango rounds the edge of the Tinga ridge, at an elevation of 11,500 feet, before the commencement of the descent to Leo. The slates rest upon the crystalline rocks, and no material change of dip would be observed in passing from the one series to the other.

The crystalline series extends from the point indicated up to (and probably beyond) the Para river, but at and beyond Chango, as will be shown further on, they are overlapped by pink limestones and calcareous slates. The lowest beds in the crystalline series at Leo are massive quartzites; these are followed by thin-bedded white and bluish-white quartzites, with some beds of mica schists. Higher up in the series the mica schists become more prominent. Some of the latter are fine-grained silicious rocks, showing no mica on the weathered surface.

The crystalline rocks, quite up to their junction with the unaltered rocks, are riddled through and through by dykes and veins of albite granite, varying in thickness from about 30 feet to the fraction of an inch. The granite is undoubtedly intrusive. It may be seen throughout the crystalline series between Leo and Chango, from the bed of the Spiti river up to the tops of the highest peaks, profusely penetrating the strata in all directions; sometimes darting across them in long zigzags, like forked lightning; at others, following the line of bedding for some distance, and then either dwindling away into thin strings, or terminating suddenly to burst out in adjacent strata with redoubled force.

The granite in the gneiss in the vicinity of Chango has already been identified as albite granite (Memoirs, vol. V, p. 154). It presents all the characteristics of the intrusive albite granite of the Wangtu section of the Sutlej valley, being a mixture of quartz, muscovite, schorl, and a snow-white felspar (*occasionally* showing triclinic striations) that scarcely weathers at all. When the schorl is sparsely scattered through the rock, the muscovite is plentiful and in good sized packets or leaves, but when the black tourmaline is abundant, the muscovite becomes very subordinate and dwindles to thin flakes of small size. In some places the schorl is profusely scattered through the rock, in irregularly shaped fragments.

Near Chango I found cyanite in mica schists. It was of beautiful cobalt blue, shading into a pearly white, but the blades were not nearly so large as those of the mineral found in the central gneiss near Wangtu. In the same locality there were some chiastolite schists near granite.

I first met with gneiss within a few miles of Chango. It showed again between the latter place and the Para river, and on the banks of that stream. Dr. Stoliczka identified the gneiss on the left bank of the Para river as the *central gneiss* (Memoirs, vol. V, p. 16), and though I saw none porphyritic in structure, I do not doubt the correctness of the identification. That the crystalline rocks I have described belong to the central gneiss series may, I think, be accepted on the evidence of their crystalline structure, and the presence in them of cyanite and intrusive albite granite, characteristic features of the typical Wangtu section. The dip of the crystalline rocks at Leo is west-by-north, but this changes gradually to west-south-west, and finally at Chango to south-west.

About two miles south of Chango a ridge of limestone rocks, the dip of which varies from south-west-by-south to south, runs up from the Spiti river and abuts on the crystalline series just where the road from Leo to Chango crosses the ridge. At this point the dip is south-west-by-south. The limestones consist of thin-bedded, pale blue and cream-colored beds, weathering from a pale pink to a yellow ochre color, intercalated with dark blue calcareous slates. The latter effervesced freely with acid wherever I tested them, but they break up into small thin slices, and look more like slates than limestones.

In a cliff overhanging the Spiti river, I found what appeared to be coralline remains in the pale-blue limestone; but they were in bad preservation and have not been identified.

In the bed of a stream to the east of Chango and between the latter village and the ridge above described, and also at the village of Chango itself, some hard dark slates are exposed. Dr. Stoliczka also mentions (Memoirs, vol. V, p. 19) the occurrence of silurian slates opposite Shalkar. The slates dip under the limestones.

On the north side of Chango the limestones distinctly overlap upon the crystalline series. To the north-east of the village, where two irrigation channels "take off," as engineers say, from the stream flowing down from between the Kakthai and Kungrang trigonometrical stations to the Spiti river, the crystalline series is to be seen in contact with the pink limestones and dark calcareous slates. The mica schists are riddled with albite granite veins up to the point of contact.

The limestones overlap the schists; and though the plane of contact dips at a high angle, the junction of the two series of rocks is evidently not a faulted one, for about a mile lower down the stream, the crystalline series again crops up and forms a cliff overhanging the river; the identity of these rocks here with those higher up the stream being established by the presence of two albite granite veins in the cliff alluded to. Further evidence of the fact that the limestones overlap the crystalline series was obtained as I journeyed onwards along the line of strike.

From Chango (elevation 10,15C feet) up to the top of the Chandan Namo ghat[1] (elevation 12,340 feet), the rocks consist of similar limestones to those

[1] Marked Ga station on the map. It is opposite Shalkar.

described as occurring in the ridge south of Chango; in both ridges white and grey quartzites occur in connection with them; but the whole hill-side is covered with talus, and only little outcrops of rocks *in situ* are seen here and there. The pink limestones at the commencement of the ascent dip north-north-east and north-by-east, but the dark calcareous slates are generally vertical or dip about in all directions. At the bridge over the Chadaddokpo the crystallines (mica schists and gneiss well riddled with albite granite as usual) re-appear in force on both banks of the stream. They appeared to extend a considerable way down the stream. Dip here north-west-by-west. On rising from the bed of the river I came again to unaltered whitish blue limestones, whilst beyond, in the same line of strike, the mica schists and granite re-appeared. In the bed of the Para river the gneiss is so riddled with granite that its metamorphic character is nearly obliterated.

Proceeding westwards from the camping ground on the banks of the Para river (elevation 10,580 feet) the rocks are at first white quartzites dipping east-by-south; then follow compact blue slaty limestones, and then a pale salmon pink limestone weathering a light ochre brown. The blue beds break up into thin slaty slices, and the whole, no doubt, are a continuation of the beds seen at Chango. They continue over the ridge down to the Ghu river. As the stream is neared the white quartzite seen on the banks of the Para re-appears, dipping east-north-east and north-east-by-east. It weathers a reddish-brown. Below it are grey quartzites, and below the latter, in the bed of the stream, is a pale whitish-grey slate sufficiently soft for a knife to cut well into it.

The pink limestones and calcareous slates in contact with the crystalline series at Chango are, I apprehend, identical with the pink limestones and slates seen at Hango; but I feel some difficulty at present in giving a name to them. They are above the silurian slates (overlapping them and resting on the crystallines at Chango), and are overlaid by the dark Lilang limestones at the Hangrang pass and Hango. They appear to occur again, as will be mentioned further on, in the same order, between Losai and the Kanzam pass. I think they answer best to the Muth middle beds, which Dr. Stoliczka correlated with the Blaini limestone of the Simla area (Memoirs, vol. V, p. 141), and in coloring the accompanying map, I have provisionally classed them as Muth middle beds. Very often both the weathered and fractured surfaces of the pale blue and pink limestones reminded me of the Blaini limestone of the Simla area

I considered it right to note (page 59) that I saw at Hango what had the resemblance of a triassic fossil, but unless and until other triassic fossils are found in the pink limestone beds, I do not think it would be safe to attach importance to the circumstance.

Proceeding onwards towards Huling, the road leads over what appears to be a continuation of the same series for a short distance, when these rocks are suddenly cut off, apparently by a fault with no great throw; the road, which follows the line of strike, passing suddenly from white quartzites to silky slates containing some beds of very pale blue limestones (both weathering reddish-

brown), being the beds of the Bhabeh series described by Dr. Stoliczka at p. 19, vol. V, Memoirs.

These rocks at first dip north-west, but eventually round to west-by-north; the change being marked by a great contortion amongst the upper rocks on the left bank of the Spiti. The silky slates are succeeded by rocks higher in the series; those described at p. 20 of Dr. Stoliczka's Memoir, *viz.*, beds of light colored quartzites and quartzite sandstones intercalated with dark slates that splinter into small thin slices. The debris of these slates imparts a very dark tint to the mountain sides, especially when seen from a distance, but whenever I tested them I found that they had a pale grey streak.

These beds on the Spiti river, between Huling and Po, have the same coloring in the accompanying map as the slates south of Leo and of the Kanzam pass; but in both of these latter regions they more closely resemble the slate series of the Simla area; and I was unable to decide from the cursory survey of the rocks along the route I followed, whether the difference in the character of the beds is due to alteration in their lateral extension, or whether they occupy a different horizon in the palæozoic series. From Dr. Stoliczka's remarks at page 21 of his Memoir, he would appear to have held the former view, and I think it is probably the right one, but the point can only be satisfactorily determined by the survey of a wider area than I had an opportunity of visiting.

Near Lari the strata become vertical for a short distance, and here I observed a thick bed of the contemporary greenstone described by Dr. Stoliczka as occurring in the palæozoic formation of Spiti (Memoirs, vol. V, p. 20). For some distance beyond Lari, angular blocks of this rock on the road side attested its presence in the cliffs above, but if it again dip down to the level of the roads, the outcrop must be buried under talus, as I did not see the rock *in situ* again.

From Lari onwards I did not observe any material change in the character of the rocks until nearing the point where the river Spiti takes a sudden north-west turn near Mani.[1] Here the strata suddenly dipping down to the river and rising on the opposite side form a sharp synclinal, along the axis of which the Spiti river runs for many miles. To the south-east the synclinal can be seen dying out among the peaks overhanging the Manirang pass, whilst to the north-west it may be traced for about ten miles beyond Dhankar, the bottom of it rising higher and higher and fading away in the mountains on the right bank of the Spiti.

This sharp bend in the strata brings down the upper rocks, and amongst them I observed a conglomerate, in a cliff overhanging the road on the left bank. There is about 40 feet of it. The matrix is a brown slaty rock; and it contains numerous pebbles of white, grey and reddish quartzite of irregular, rounded and subangular shapes. The largest I saw was about 4 inches in diameter.

This rock resembles the Blaini conglomerate of the Simla area. On the conglomerate rests a limestone containing numerous fossils, but in such bad preservation that none have been clearly identified. This was followed in the ascending

[1] Mani is on the right bank below Dhankar.

order by a brown sandstone which doubtless belongs to Dr. Stoliczka's carboniferous series. Then came talus, then slates followed by limestones interbedded with slates, and finally massive blue compact limestone (Lilang), weathering blue and brown in irregular patches.

The Lilang limestones which are exposed from this point almost the whole way up the valley are very like typical Krol rock. In color, in the thickness of their beds, and in often containing tortuous white calcite markings, they much resemble the rocks of that series. As I have described, the Lilang limestones of the Spiti valley, and the dark limestone seen at the top of the Hangrang pass, as both resembling typical Krol rocks, I need perhaps hardly add that they also closely resemble each other. In the absence of fossil evidence to the contrary, I conclude that the upper Hangrang beds belong to the Lilang series.

I may mention in passing, that I saw the conglomerate again a few miles beyond Dankar, on the left bank of the Spiti, a few feet only above the bed of the stream. A considerable thickness of a light colored calcareous sandstone containing pebbles similar to those in the conglomerate opposite Mani is overlaid by a brown slaty rock, also containing similar pebbles. This conglomeratic sandstone is composed of grains of unequal size cemented together with carbonate of lime and earthy matter exhibiting rusty reddish spots on the fractured surface. It appears to have been squeezed up from below the strata at the point indicated, having been subjected to great strain and contortion.

The section from Dankar up the Spiti is described at pp. 26, 33 of Dr. Stoliczka's Memoir, and it appears from the remarks at p. 33 that between Losar and the Kunzam pass, the section is a repetition of that described by Dr. Stoliczka between Muth and Kuling. At the point where the road turns up the Lichu valley between Losar and the Kanzam pass, I observed a thick bed of pink limestone; but as a storm of two and half days' duration had covered the whole country with snow, and inflicted on me a sharp attack of snow-blindness, I was unable to explore this locality in detail.

The slates re-appeared near the Kanzam pass. From the top of the pass (elevation 14,931 feet, T. S.), down to Kátza, a halting place where the Chota Shigri river joins the Chandra, they resemble typical Simla slates. Dip north-east-by-north. On the left bank at Kátza the dip suddenly changes to very high south-south-west, and the slates are more silicious, and some of them have a micaceous glaze previously absent. The central gneiss appears with the Bara Shigri river, and huge blocks of it form a prominent feature in the moraine of the Shigri glacier. As I was making forced marches over heavy snow, I could not linger to explore this interesting neighbourhood, but Dr. Stoliczka states (p. 15 of Memoir) that "the boundary of the gneiss and of the *overlying*[1] silurian rocks" may be seen on a stream north of the Shigri glacier, six miles in a straight line south of the Kanzam pass. The Chota Shigri is probably the stream indicated.

[1] *See* also p. 17 and p. 341 of Vol. V.

The Shigri moraine passed, the talus of the mountains on the left bank of the Chandra consists of nothing but blocks of central gneiss, and finally that rock itself crops out *in situ* on the road side.

The absence of blocks of foreign rocks, I notice in passing, is hardly favourable to the view that the glaciers of the upper Chandra became confluent and flowed down the valley in recent geological times.

The central gneiss of the Chandra valley is often granitoid, and is penetrated by the albite granite (Memoirs, vol. V, p. 170). It extends to near the top of the Hampta pass (elevation 14,000 feet), where mica schists show under it, dipping north-west. Descending into the Kulu valley the gneiss shows for a considerable way, when it is succeeded by mica schists. The dip flat on the top of the pass, gradually veers round to west, and this again brings down the gneiss. The dip, which is usually low, wavers about sometimes in one direction and sometimes in another, being south-east at Jagatsukh and north-east at Dwára.

The continuance of the central gneiss in the micaceous and silicious schist beds, up to a mile north of Naggar, is attested by the presence of angular blocks on the road side that have tumbled down from cliffs above. From this point to Bajaura the metamorphic rocks consist principally of a dull brown mica schist, that smells earthy on the fractured surface, and generally does not show any indication of mica on its weathered surface.

The section between Sultanpur and Narkanda has been described by Mr. Medlicott (Memoirs, vol. III, p. 57), but I may briefly note, to complete this sketch, that the Sutlej valley limestones suddenly crop up about a mile south of Bajaura, and abruptly disappear about two and half miles north of Manglaur, where schists similar to those described as occurring between Naggar and Bajaura re-appear. The gneiss shows in force several times between Kot and Dulash, and frequently from thence down to the bed of the Sutlej. On the Kotgarh side, the dip coinciding with the slope, it is the only rock seen for 1,900 feet of vertical height above the river. From this point to within a few miles of Mattiána the rocks consist of schists similar to those south of Naggar in the Kulu valley.

The "graphitic schists" on the north side of the Jalori pass[1] are very similar to rocks seen round Kotgarh, and between the latter place and the Nogli river south of Rámpur. These rocks puzzle me very much. They are dark carbonaceous schists or slates with a micaceous glaze on them, and by their disintegration make coal-black earth. They are associated with limestone which occurs in more than one place on the north side of the Jalori pass, and a band of which crops up in several places under Kotgarh and along the Sutlej valley up to the Nogli river. Are these Infra-Krol rocks, lying closely on the crystalline series, or do they belong to the latter? The former would appear to me probable.

But without drawing any inference from these doubtful rocks, my observations during the present and previous tours show that, on the north as on the south of the central gneiss, the upper calcareous groups of the great palæozoic series originally overlapped the slaty series and rested on the crystallines.

[1] Mem. G. S. I., Vol. III, pt. 2, p. 57.

GLACIATION.

On the top of Chandan Námo pass (close to the Ga station, above Chango), I observed a considerable number of rounded river boulders of red quartzite and other rocks that do not occur locally. The red quartzite was probably derived from the Muth beds in Spiti. Beyond and at a lower level, I occasionally met with rounded boulders of trap, doubtless from the palæozoic formation of that valley (Memoirs, vol. V, p. 20), whilst 670 feet above the Para river, I observed numerous horizontal beds of *river* conglomerate. The boulders on the top of the Chandan Námo pass were undoubtedly rounded in the bed of a river by the action of the water, and there are no grounds for supposing that they were ice borne. The only explanation that appears reasonable to me is that the bed of the Spiti river was formerly as high as the top of the Chandan Námo pass, which is about 2,400 feet[1] above the present bed of the Spiti river.

Dr. Croll, in chapter XX of his Climate and Time, and Professor Geikie in chapter XXV of Juke's and Geikie's Manual of Geology (3rd edition, 1872), discuss the rate of the erosion of rock surfaces evidenced by the amount of sediment annually carried down by the river systems; and the rate of erosion at which seven rivers specified remove one foot of rock from the general surface of their basins is said to vary from 6,346 years in the case of the Danube, and 6,000 years in the case of the Mississippi, to 929 years in the case of the Po. The rate given for the Ganges is one foot in 2,358 years.

Professor Geikie takes "the proportion between the extent of the plains and table lands of a country and the area of its valleys to be as nine to one," and assumes "that the erosion of the surface is nine times greater over the latter than over the former area." If, adopting this principle, we assume that within the mountain valleys of the Gangetic basin the erosion is nine times more rapid than over the rest of the basin, this would make the rate of erosion over the mountain area one foot in 262 years.

But the agents of denudation are much more powerful within the river basin of the Ganges than within that of the Sutlej. The watershed of the Ganges embraces a large area of exceptionally heavy rainfall, rising as high as 524 inches per annum in the Khasi hills, being "the greatest rainfall in the world," (Huxley's Physiography, p. 48); and within this area the agents of denudation must operate with exceptional activity. The rainfall over the watershed of the Sutlej, on the other hand, is comparatively light, being probably greatest at Simla, where the average for 15 years, from 1862-63 to 1876-77, was 75·1 inches. As you proceed higher up the Sutlej, the fall decreases, and beyond Wangtu becomes extremely light.

[1] Measured by my aneroid barometer, the elevation of the Spiti river at Leo is 9,550 feet, and at the confluence of the Ghu river 10,125 feet, the distance between the two points, measured straight across the map, being 13 miles. The top of the pass measured by my barometer is 12,340 feet. The weather being fine and cloudless, there could have been little variation from climatic causes.

Mr. J. B. Lyall, in his settlement report of the Kángra district (1874), states (page 164) that "light showers of rain occur" in Spiti, "in July and August; and in winter, snow falls only to the depth of $2\frac{1}{2}$ feet." As "10 inches of snow roughly represents 1 inch of rain" (Huxley's Physiography, p. 63), $2\frac{1}{2}$ feet of snow is equivalent to a rainfall of 3 inches. Even on the assumption that the fall of snow on the high peaks and passes is greater than that mentioned by Mr Lyall, the average for the whole of the Spiti valley cannot be in excess of 10 inches in the year, and the bulk of this falls as snow.

No hot winds penetrate to these elevated and mountain-locked regions to cause sudden thaws; the clear frosty air is usually without a cloud, and the snow "melts gently" (Lyall, p. 162).

That denudation proceeds slowly in the region under consideration will, I think, be evident when we consider that though the Spiti (a tributary of the Sutlej) flows over comparatively soft limestones and friable slates, whilst the Sutlej at Wangtu has to cut its way for miles through intensely hard granitic gneiss, yet the bed of the Spiti opposite Shalkar is still 4,724 feet above the Sutlej at Wangtu,[1] the distance between the two points being only 45 miles as the crow flies.

The deepening of the bed of the Satlej at Wangtu must be a very slow process, but clearly the excavation of the Spiti valley is a still slower operation.

The fall of the Sutlej at Wangtu is about 50 feet per mile.

I think, with reference to the only data we have to enable us to form a rough idea on the subject, that the rate of the deepening of the bed of the Spiti at the point under consideration is probably not more rapid than 1 foot in 400 years. At this rate it would require 960,000, or in round numbers say about one million of years,[2] for the excavation of the Spiti valley between Shalkar and the Ga station.

At the rate of 1 foot in 400 years, the total depth excavated in 80,000 years would be 200 feet only; so that if the last glacial epoch terminated as recently as 80,000 years ago, the date fixed by Dr. Croll on astronomical data (pp. 325-327, Climate and Time), the Upper Sutlej and Spiti rivers, and the agents of denudation operating on the slopes of their watersheds, cannot have effaced the broader marks of the work done by glaciers during that period. If then any *great* increase of glaciation during the last glacial epoch took place in the region under consideration, we ought to find decided traces of ice sculpture in our Himalayan upland slopes and valleys.

A similar conclusion appears to have been arrived at by experienced geologists regarding England. "Post-glacial denudation generally," states Mr. Good-

[1] The Sutlej at Wangtu, 116 miles beyond Simla, is 5,200 feet above the sea.

[2] This is less than half the rate adopted by Geikie for his average valley. "For we find by a simple piece of arithmetic, that at the rate of denudation which we have just postulated as probably a fair average, a valley 1,000 feet deep may be excavated in 1,200,000 years, a period which, in the eyes of most geologists, will seem short enough." Juke's and Geikie's Manual, p. 431.

child (Q. J. G. S., vol. XXXI, p. 99) "has affected so little, that by far the greater part of the present surface-configuration has in one way or another resulted from the former presence of the great ice sheet."

Bearing this principle in mind, I looked around me, during my recent tour, for the evidences of former glaciation. I do not know whether any one has ever supposed that the Hímalayas were covered during the last glacial period with an ice cap, but I may note that whilst I saw nothing to favor such an idea, I saw much to negative it. The contour of the hills and valleys in those parts of the interior of the Himalayas that I have visited is sharp and angular, and where rounded outlines are seen, they are sufficiently explained by the action of sub-aërial forces on comparatively soft and friable rocks.

But setting aside the idea of an ice cap, the question remains—was there formerly any great extension of local glaciers, and if so, within what limits? To this question I answer that, whilst I saw evidence of the former extension of existing glaciers, I saw nothing during my tour to lead me to believe that these glaciers had ever, within a reasonable geological period, extended lower than 11,000 or 12,000 feet above the sea.

On looking down from a high vantage ground, deep narrow side valleys may be seen on the Upper Sutlej, below that level, in which the course of the streams flowing through them is so sinuous that the sharp headlands formed by their sudden bends interlace like the nuts of cogwheels working into each other. The flow of ice in a glacier being analogous to the flow of water in a river and its tributaries, a grand glacier filling the valley of the Sutlej would not have prevented the flow of ice from the side glaciers into the main glacial stream. But had these side valleys ever been filled with glaciers, the sharp interlacing headlands would have been gradually worn down to smooth surfaces, and the valleys straightened and widened.

The only valley in the Himalayas I have yet seen that is shaped like a glacier valley is the Spiti valley. The greater part of it is more than 11,000 feet above the sea, and its bottom, especially in the upper half of the valley, is broad and flat, whilst the bounding mountain sides rise abruptly in a wall-like manner at a high angle, and send no sharp projecting spurs into the valley. But if, as I think highly probable, the upper portion of the valley owes its shape, in part at least, to the action of ice, the period during which a glacier flowed down the straight course of the Spiti river must have been very remote; for I noticed about half the way up the valley a side valley partaking of the character of those described above; whilst the flat boulder bed which, in the upper valley, rises high above the river, seems to owe its origin in part to the action of the river, and in part to talus shot down from the bounding cliffs. It is not of glacial origin.

I now proceed to note the evidence which I obtained of the former extension of glaciers. At the head of the Spiti valley the Lichu river flows down from the peaks that surround the Kunzam pass, into the Spiti. There is probably a glacier up the side valley crowned by the snowy peak 20,581 feet high, but there is now no

glacier in the Lichu valley between the Spiti and the Kunzam pass. About four miles in a straight line from the top of the Kunzam, a spur from the Shilatakar peak runs down to the Lichu river, and an ancient glacier in its course down the valley must have ridden over it. The rocks there, at an elevation of 14,000 feet, are thinly laminated slates, the dip of which is perpendicular, and the strike of which points across the valley at right angles to what must have been the course of the ancient glacier. The slates generally break up on the surface in thin flaky slices, but here and there long patches of the rock are *moutonnée*, polished and striated. The polishing is even now sufficiently perfect to obliterate all traces of the lamination of the slates. The striæ are well marked; they are generally in a direction of the axis of the valley, though they often cross each other at inconsiderable angles. As evidence of former ice-action nothing would be more complete and perfect. The splinting friable slate on which this ice-action is recorded is the last sort of rock on which I should have expected to find it.

Regarding the recession of glaciers, I note that the Big Shigri, as evidenced by its terminal moraine, has shrunk somewhat; but in the case of the Pirad glacier, the next to the west of the Bara Shigri, the shrinking is very evident. The road passes within about quarter of a mile of this glacier, and from either side of it a large lateral moraine may be seen curving down the valley until it reaches the river, three-quarters of a mile, or a mile, from the present end of the glacier.

Again, the head of the valley, up which the road to the Hamta pass lies, is filled by a glacier that extends a little below the entrance to the pass. The old terminal moraine of this glacier may now be seen about one and a half miles lower down the valley, rising in steep banks some 50 or 60 feet above the talus, shot down from the sides of the valley.

About a quarter of a mile below the Pirad glacier, on the side of one of the moraines, there is a huge block of the central gneiss, well rounded, polished and striated on all sides but one.[1] The impression I derived from examining it was that it must have originally been a boss of rock projecting from the side or bottom of the glacier bed, and that it was ultimately torn away from its parent rock and deposited where it now rests. I did not measure the block, but it cannot be smaller than 50′ × 50′ × 50′. One side has been ruptured from the block, apparently by the action of frost on water filling a crack, and its pieces rest by its side.

[1] Exclusive of the side on which it rests, which, of course, cannot be seen.

NOTE ON A RECENT MUD ERUPTION IN RÁMRI ISLAND (ARAKÁN) BY F. R. MALLET, F.G.S., *Geological Survey of India.*

In the account of the mud volcanoes of Rámri and Cheduba given in Volume XI, part 2, it is mentioned that there is a notion prevalent amongst the islanders that eruptions take place more frequently during the rains than at other times of the year. The few dates of eruption on record, in as far as they go, do not bear out this idea, but the number is too small to generalise upon.

Were the idea of an increase in activity during certain months of the year confined to the unsophisticated inhabitants of these islands, the point might perhaps be scarcely worth examination. A greater tendency to eruption at certain periods has, however, been suspected to exist in some other parts of the world. It is stated by Dr. Horsfield, that eruptions from the mud volcanoes of Java are more violent during the rainy season than at other times, and M. Dubois de Montpéreux mentions that out of six eruptions from the mud volcanoes near the entrance to the Sea of Azov, five occurred between February and the 10th of May, the only known autumnal eruption having been on the 5th September.[1] Whether, therefore, the belief of the Arakán islanders be well founded or not, the point is worth investigation.

In this connection the following letters, which have been placed at the disposal of the Geological Survey by the Commissioner of Arakán, are valuable as the first contribution towards a catalogue of eruptions sufficiently extended for generalisation. It is hoped that we may be able to make such in time through similar communications from the Officials of the Rámri district, and others who may take an interest in the subject.[2]

From CAPTAIN J. BUTLER, Deputy Commissioner, Kyouk Phyoo, to the Commissioner of Arakán, Akyáb,—No. 35-12, dated the 16th July 1878.

In compliance with the instructions conveyed in your letter No. 732-165, General Department, dated 22nd ultimo, I have the honor to state that the following individuals were

[1] Records, G. S. I., Vol. XI, p. 201.

[2] It will be seen by reference to the paper quoted above, that there are some other points, also, connected with the eruptions, concerning which our information is not sufficiently detailed. The following list of questions may perhaps be useful as a guide in obtaining information from the villagers:—

1. Informant's name and village.
2. Locality at which the eruption took place. Name of village, with distance and bearings from one or two well-known places.
3. Date of eruption, and time of day at which it commenced.
4. Was it preceded or accompanied by any perceptible earthquake?
5. How long did the eruption last? Did it begin suddenly, or increase gradually in violence, and did it end suddenly or gradually?
6. Were there any flames during the eruption? If so, how high did they rise above the top of the hill, when largest, and how long did they last? Was the flame continuous or intermittent?
7. What is the shape of the hill, and its height? Was it formed entirely during the recent eruption, or was part of it there previously? Is it conical, and is there a basin or hollow (crater) at the top? If so, what is the diameter of the hollow, and does it contain mud?

examined by the Kin Thoogyee, relative to the volcanic eruption which took place in his circle a few months ago, *viz.* :—

1. Kulla-kyee of Kon-boung Tau Village,
2. Ya-ba Hkyoung of Peu-lay-na ditto,
3. Pau Hla Oo of ditto ditto,
4. Tha Htoon Hpyoo ditto ditto,
5. Tha Htoon Oung ditto ditto,
6. Ya-ba Oung of Loung Hkyooein ditto,

and from their collective evidence the Thoogyee has communicated the following :—

1. The eruption occurred near the village of Peu-lay-na, a spot bearing about 460 yards north of the above village, 1,000 yards west of the Yua Ma village, and ¼ of a mile east of the sea-shore.

2. It occurred on the 19th of March 1878, at 7 o'clock in the morning.

3. No earthquake occurred, the earth merely cracked, and from the fissure a hill began gradually to rise.

4. The eruption lasted 11 days, and began increasing gradually day after day, ending in the same manner. This was ascertained by means of a post which was put into the earth for the purpose of watching the height of the hillock as it increased. A few days, however, before the eruption ceased, the post was found lying some 14 or 15 cubits distant from the place where it had been put in.

5. No flames occurred at the time of the eruption : a lad, however, who happened to be close to the spot, accidentally dropped into the crater a box of matches, when immediately a large flame to the height of about 25 cubits above the top of the hill issued forth, and which continued burning for two days and a night before it went out.

6. The shape of the hill is said to resemble an inverted boat, and its height is 18 cubits. There was previously in the same spot a small hill about 9 feet high, and on this hill the eruption took place. The hill is flat on the top, cracked in several places, and the cracks filled with mud.

7. The lava or stuff[1] thrown up was mud mixed with stones, and the mud thin and watery; when first thrown out the mud was warm. Inside the cracks it is very hot when felt by the hand. The stones were small in size, and were not thrown up much higher than the summit of the hill.

8. There is another hill of the same kind as this one in the neighbourhood which was formed over a hundred years ago.

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8. Was the stuff thrown up mud only, or mud mixed with stones? Was the mud thin and watery, or thick? Was it cold, warm, hot or very hot when first thrown out? How large were the biggest stones thrown out, and how high were they thrown?

9. Are there any other hills of the same kind in the neighbourhood, and if so, have any of them been formed during the remembrance of the present generation; if so, how many and when?

Any further information will also be acceptable.

[1] Specimens sent to the Geological Museum were light grey mud and pieces of grey shale. A few pieces were reddish, doubtless from having been exposed to the heat of the flames.—*Vide* Vol. XI, pp. 196, 201. 202.

9. The Burmese, as a rule, are very superstitious in matters of this sort, and generally ascribe such a phenomena to the work of a dragon (Nagah).

From CAPTAIN GEORGE ALEXANDER, Officiating Deputy Commissioner, Kyouk Phyoo, to the Commissioner of Arakán Division, Akyáb,—No. 3, dated Camp Rámri, 11th December 1878.

I have the honor to submit a further report on the subject of the volcanic eruption near Moo-yin in the island of Rámri, and in continuation of my letter No. 35-12 of 1878.

The mound first made its appearance on the night of the 18th March 1878; at least the first people who saw it were some women, who went out to cut wood before dawn on the morning of the 19th, and came across a mound gradually rising from the earth, and being frightened, believing that it was a "Nagah Doung", or hill raised by a dragon, they ran away. They saw no fire, nor did they perceive any earthquake. They state that the mound continued rising for 12 days, and that it was on fire for a day and a night. Lah Bah Chyoung, the writer of the circle Thoogyee, who visited the spot at about noon on the day in question, says he found smoke and fire issuing from cracks in the mound when he arrived, but states that the surface of the ground was smooth and hard; that the earth was being forced out of an area of about three bamboos or 36 feet in length, and gradually made its way westward towards the sea. It appears to be doubtful whether the mound itself vomited fire, or whether it was set on fire by a small child with a cheroot; at any rate it was on fire on the day after its appearance, and the flame burnt for two days, not steadily and regularly, but spurting up into the air by fits and starts, for some 20 or 30 cubits; there was a strong smell of earth-oil whilst the mound was on fire, and it is described as having been so powerful and pungent as to make the women near giddy; there appears to have been no active sudden eruption, merely an upheaving of the earth gradually. And the villagers state that sticks planted 6 inches or a foot in the ground in the evening would be found to have been carried considerably westward by morning, the first night 14 cubits; but the distance kept decreasing inversely as the days went by. This information is gathered from the women who first saw the mound and from other residents close by.

Directly inland, and at a distance of some 300 or 400 yards from the present upheaval, is a conical hill which has the appearance of being one of volcanic origin. The present elders of the village state that in the year 1146 (Burmese era), or 94 years ago, a volcano appeared which threw out large quantities of stones and residue, and gradually formed a hill which some 65 years ago was about 23 feet high, and which is now estimated at about 40 feet high, although it is difficult to say where the hill begins, and the top is considerably more than this height above the surrounding paddy cultivation. This mound is called by the Arakanese "Nagah Bwai" or dragon's circle, and has been in active eruption some four or five times during the life of one of the present elders, at a few hours at a time, and the stones thrown out on each occasion have caused the hill to increase in bulk. Whenever the eruptions took place at the Nagah Bwai hill, the same strong smell of earth-oil was perceivable; the last eruption took place about five years ago. Some of the stones found at the spot where the last upheaval of the earth occurred have been collected by myself personally, and as the Officers of the Geological Department expressed a wish to have some of these stones, I forward the same, as they may cast some light on the causes that influenced this phenomenon of nature.

There seems to be little reason to doubt that earth-oil in one form or another was the disturbing influence.

ON BRAUNITE, WITH RHODONITE, FROM NEAR NÁGPUR, CENTRAL PROVINCES, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

Some time ago, Mr. W. Ness, Mining Engineer in charge of the Warora Collieries, sent a parcel of about 20 lbs. of manganese ore to the Geological Museum, with a notice of the locality in which it had been found. It appears from this that the ore occurs on the south-east side of Munsur Great Trigonometrical Station, a hill three miles west of the town of Rámtek, which is about twenty miles north-east of Nágpur. Mr. Wilson, Executive Engineer of the Kanhán Division, who has visited the place, describes the outcrop, which strikes north-west, south-east, as being visible for about a quarter of a mile, with a thickness of about 10 feet. Mr. Ness, however, is inclined to think that some portions are inferior to the samples sent to the Museum.

The latter are finely-granular massive, with here and there portions which are indistinctly crystalline on a larger scale. The specimens are bounded on two opposite sides by planes which appear to be joint-faces, approximately perpendicular to which the mineral is intersected by irregular, more or less elongated cavities: the larger of these are about an eighth of an inch across, and some as much as three or four inches long: others are visible only under the lens. Many of them are partially, or almost entirely, filled by a translucent, light brownish-red and yellowish, indistinctly crystalline mineral, which proved on examination to be rhodonite.

The color and streak of the manganese ore are brownish-black. Hardness about 6·0. The specific gravities of three different samples were 4·22, 4·36, and 4·46, the differences (and the inferiority in gravity to that of braunite in crystals) being doubtless partly due to minute cavities.

On analysis the mineral yielded, counting all the manganese as sesquioxide, according to the formula more usually adopted for braunite—

Manganese sesquioxide	78·64	79·39
Iron sesquioxide	9·78	9·87
Lime	1·20	1·21
Magnesia	tr.	tr.
Oxygen in excess of that required for M^2O^3 ...	1·65	1·67
Silica	6·00	6·06
Phosphoric acid	·21	·21
Combined water	2·61	2·63
Hygroscopic water	·60	...
Disseminated rhodonite	·35	...
	101·04	101·04

The second column gives the composition exclusive of hygroscopic moisture and thodonite, scattered minute grains of which can generally be detected by the lens even in the most homogeneous specimens. Being but little acted on by

hydrochloric acid, it is left undissolved, together with gelatinous silica. The excess of oxygen, and the presence of water, show that the braunite is not in a pure state, having probably undergone partial alteration.

The ore contains 55·27 per cent. of manganese and 6·91 of iron. The main use of manganese ores, however, is as oxidizing agents, their value depending on the amount of available oxygen they contain. Pyrolusite, or peroxide of manganese, the richest in oxygen and most valuable ore, contains when pure 18·39 per cent.; and ores are generally valuated by the percentage of peroxide they contain, or more correctly speaking, the percentage of peroxide, to which the oxides they contain are equivalent in available oxygen. The average run of ores met with in commerce contain 60 to 75 per cent. of peroxide = about 11 to 14 per cent. of available oxygen. The Nágpur braunite contains 9·71 of available oxygen = 52·80 per cent. of peroxide. As an oxidizing agent, therefore, it cannot be classed as more than fairly good.

A deposit of the same class of manganese ore was found by Mr. W. T. Blanford in 1872, at the village of Kodaigowhan (near Khappa), 20 miles due west of Munsur, Great Trigonometrical Survey.

PALÆONTOLOGICAL NOTES FROM THE SATPURA COAL-BASIN, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

In the beginning of last year (1878) I had an opportunity of traversing from east to west a portion of the great Sátpura coal-basin, with the special intention of collecting fossils at certain places. Taking as guide the last report on this ground[1] I started from the Gádarwára station, Great Indian Peninsula Railway, for the Mohpáni coal-field, of which a brief description was published[2] in 1870.

Mohpáni field.

With assistance of the manager of the Mohpáni coal mines, Mr. Maughan, I was enabled to collect what fossils were to be got, which to some extent permitted of a comparison of the Mohpáni coal seams (in part at least) with some other known horizon of the Indian coal strata, as given in my recently published flora of the Talchir sub-division.[3] I shall repeat only what is necessary for general understanding in the present paper.

In the report referred to, the close relation of the Talchirs and the coal beds in the Mohpáni coal-field is pointed out; and this view seems to be supported by the fossils, which bring these coal seams on the horizon of the Karharbári coal beds, which latter were recently shown to belong to the Talchir division.

Fossil plants.

The fossils which I collected were found in a band of shale in the uppermost of the Mohpáni coal seams, which are outcropping in the valley of the Sitariva river, on the right bank of which the only mines of importance at present are situated.

[1] H. B. Medlicott: Mem. Geol. Surv. of India, Vol. X.
[2] H. B. Medlicott: Rec. Geol. Surv. of India, Vol. III.
[3] Pal. Indica, Ser. XII, 1.

The fossils are few in species, although numerous in specimens, and I could observe—

Equisetaceous stalks, some of which, I think, are of *Schizoneura; Gangamopteris*, pretty frequent, both in the original form *G. cyclopteroides*, and as a variety, *i. e.*, *G. cyclopteroides*, var. *attenuata*. *Glossopteris* almost equally numerous as *Gangamopteris*.

This distribution of the fossils appeared to me to be similar to that in the 3rd seam of the Kaharbári coal-field, and as I endeavour to show in the paper referred to that this seam also is to be considered as belonging to the Karharbári beds, there would be no objection to the Mohpáni seams being considered also as on the horizon of the Karharbári beds.

Parasuchian crocodile at Jhirpa.

From Mohpáni I moved towards Pachmari, over ground formed of Mr. Medlicott's Bágra and Denwa groups. Close to Jhirpa, on the right bank of the Denwa, a specimen of a large scute of a *Parasuchian* crocodile was picked up by Mr. Hughes two years ago, and it was therefore my object to examine the place, if more remains could be found. I followed the river for some distance in north-western and western direction, but not a fragment could be discovered; so I crossed the Denwa and moved on to Singanáma, on the road from Bankheri to Pachmari, quite close to the boundary between the Denwa group of rocks and the next lower group, the Pachmari sandstone.[1] To the east of Singanáma, about 1¼ mile, in the gorge of the Denwa, the rocks are fully exposed, and a little to the south of the village Moár, on the right bank of the river, the junction of the Pachmari and Denwa groups is well seen, when it is clearly observed that the Pachmari sandstone dips without any unconformity beneath the Denwa group with the same northerly dip. From Moár I went all along the Denwa valley to the north, back to Jhirpa, in search of fossils in the Denwa group, but also this time nothing was found. There is only one more locality where some organic remains were found in the Denwa group, *i. e.*, far to the west near Kesla on the road from Shápur to Itársi, where Mr. Medlicott procured some plant remains in a very crumbling mottled shale, which, after close examination, proved to belong to *Glossopteris*. This is all our palæontological knowledge of the Denwa group up to date.

Section at Moár.

Plant remains in the Denwa group.

Pachmari sandstone.

Proceeding from Singanáma to the south-west towards Pachmari, the ground rises rapidly up to the Pachmari plateau, which has an elevation of 3,481′, the surrounding hills, specially to the south and south-west, being much higher, rising to 4,384′ in the Mahádeo hill,

[1] I may perhaps mention, that before crossing the Denwa river near Jhirpa, I was encamped at Mauljhar on the road from Chindwára to Bankheri, to the south-east of which near Anoni-Dhána, there is a hot spring with exhalations of inflammable gas; it is at the head of a small nalla which receives its water from this spring, which is pretty strong, and the gas escapes at about ten places; at the source the water had a temperature of 130°F.; below this it is collected in a sort of a small tank, where it shewed 102°F., and from here it passes into the nalla. It is, of course, in high estimation with the natives, and close to it is a primitive temple of Mahádeo with a Jogi in attendance.

to 4,317′ in the Cháoradeo, and to 4,454′ in the Dhupgarh. Close to Singanáma we pass from the Denwa group on to the Pachmari sandstone, of which the whole Pachmari plateau as well as the mentioned hills consist. This Pachmari sand stone proved, in spite of careful examination, unfossiliferous.

Proceeding from Pachmari southwards, the road, always over Pachmari sandstone, leads close by the Mahádeo hill, passing the famous Mahádeo cave in the northern flank of the hill; from this cave the descent into the upper valley of the Denwa is very rapid, down the steep and abrupt slopes of the southern side of the plateau. About 1¼ mile before reaching the Denwa the slope becomes more gentle, and before reaching the police station at foot of the Pachmari range (which is about ¾ of a mile from the Denwa) there is a change of rocks, *i. e.*, under the Pachmari sandstone there appear soft, sandy, micaceous shales of greenish, yellowish, or brownish-yellowish colour, which apparently have the same northerly dip as the overlying Pachmari sandstone; that this is the case I have found further on. Here these shales proved unfossiliferous. Similar shales occur further to the north-west near Almod and Borighát, where they were found to contain only some indistinct plant impressions.

Shales under Pachmari sandstone.

In his report on the Sátpura basin, Mr. Medlicott, speaking of his Bijori horizon, mentions two possibly different bands, of which the higher might be distinguished as Almod beds ; and it appears to me that the shales which I just mentioned as cropping out under the Pachmari sandstone might possibly represent these Almod beds ; because, when proceeding further to the south close to the Denwa river, the shales change somewhat in appearance, they become a little harder, greyish and grey colours appear, and they are fossiliferous. In position they are lower than the shales mentioned before, both having the same dip. To have a better opportunity and more time to collect fossils I crossed the Denwa river near Sangakhera Dhána and encamped at Barikondam, where I was also close to the spot where the reptile said to be *Archegosaurus* was found in this lower horizon.

Bijori horizon.

The place where I collected fossils in the shales lies directly to the north of Barikondam, on the left bank of the Denwa river, between this and the police station at the foot of the Pachmari range. The shale crops out at the base of a small hill, on the eastern slope of which the road from Pachmari leads to the Denwa river, cutting through shales containing fossils. A little to the east of this hill, but still before crossing the Denwa river (coming from Pachmari), in a small nalla which the road has to cross, an instructive section is exposed showing the relation of the strata south of the Pachmari range to the Pachmari sandstone, as follows, in ascending order:—

Fossil plants in the Bijori horizon.

a. Dark-grey carbonaceous micaceous shales dipping north at about 15°, containing *Vertebraria*.

b. Greenish-reddish shales slightly micaceous.

c. Coarse thin-bedded sandstones, with the same northerly dip.

Above these sandstones is a series of sandy micaceous shales, which in this place contain no fossils, but which I believe to be the same as those at the base of the hill mentioned as on the left bank of the Denwa (north of Barikondam) where I obtained fossils; above these sandy shales is a bed of fine earthy bluish-grey or reddish-grey shales with plant fossils. Above these there would come in the sandy micaceous shales which I mentioned before as immediately below the Pachmari sandstone, and then these sandstones themselves, all apparently with the same dip. I obtained the following fossils from these localities :—

a. From the base of a small hill on the left bank of the Denwa river north of Barikondam in brownish-yellow, greenish-yellow, sandy and earthy micaceous shales which do not split regularly; the fossils are plants only and very fragmentary—

Glossopteris communis, Fstm.

Glossopteris with horizontal broad meshes (called in manuscript *Gl. damudica*).

Glossopteris, another form with distinct polygonal meshes, which form occurs also in the Rániganj group of Bengal, and which will be described as *Gl. retifera*.

Pecopteris comp. *angusta*, H. (*Merianopteris angusta*, H.). This species occurs in the Trias of Europe. A form of the same genus is known also from the Rániganj group.

Diksonia (comp. *Concinna*), a form which appears to me to be the same as that found by Mr. Hughes in the Rániganj group of the Jherria coal-field, and figured by me in 1877.[1]

b. To the east of the place just mentioned fossils were found, as already stated, in fine earthy light grey, bluish-grey or reddish-grey shales which appear to me to be above these shales. The fossils were—

Equisetaceous stalks, of which some may belong to *Schizoneura*, as this genus was found in this horizon.

Vertebraria indica, Royle; small specimens.

Glossopteris predominant; different forms.

Glossopteris communis.

Glossopteris indica, Schimp. (one specimen with little oblong marks as if indicating the Sori).

Glossopteris with broad horizontal meshes (*Gl. damudica*).

Glossopteris leptoneura, Bunb.; narrow leaflets.

Gangamopteris, a form with small roundly ovate leaves.

A round winged seed of the genus *Samaropsis*, Göpp.,[2] much resembling Heer's *Samarops rotundata*.[3]

Some other small seeds, not winged, resembling very much seeds of the same kind from Damuda rocks in South Rewa, collected by Mr. J. G. Medlicott.

Other fossil plants in the Survey collections.

Besides these fossils collected by myself, there were some other specimens from the same district in our collections. One lot of about fifteen specimens was labelled, "Upper Denwa valley near Barikondam;" the fossils are plant impressions in an earthy-reddish

[1] Rec. Geol. Surv. of India, Vol. X.

[2] *Fructus samaroideus, membranaceus compressus, margine alatus, monospermus.*

[3] Heer: Flora fossilis arctica, Vol. IV; Jura flora Ostsibiriens, etc., p. 80.

shale, and there is little doubt that they come from a similar bed of shales to that mentioned before as above the sandy micaceous greenish-yellowish shales with fossils. They comprise—

Schizoneura gondwanensis, Fstm. The same form as in the Ràniganj, Jherria, and Hingir coal-field.

Glossopteris communis, Fstm. The same form as in other places.

Besides these there is a single specimen labelled "Denwa naddi, Pachmari." It contains—

Trizygia speciosa, Royle (*Sphenophyllum trizygia*, Ung.), which chiefly occurs in the Ráni-ganj coal-field (Ránignnj group), in the Talchir coal-field (Barákar group), and is doubtfully quoted from the Damuda rocks at Pankabári.

There is no doubt that this specimen also comes from this fossiliferous zone of shales in the Bijori horizon in the Upper Denwa valley.

The Bijori horizon represents the Kámthi-Ráníganj group.

If we now consider the fossils mentioned above as coming from the Bijori horizon in the Denwa valley, *i. e.*, *Schizoneura gondwanensis*, Fstm., *Trizygia speciosa*, Royle, *Vertebraria indica*, Royle, *Glossopteris* in various forms, *Pecopteris angusta*, H., etc., we find that all these occur also in the Ráni-ganj group in Bengal, so that the fossiliferous band is correctly considered as representative of this group in the Sátpura coal basin, in which case those sandy micaceous unfossiliferous shales immediately below the Pachmari sandstone, and the beds of the same position near Almod and Rorighát (which have been distinguished as Almod beds), would perhaps represent the Panchet group of Bengal, this the more if we consider the close relation of this group in Bengal with the Ràniganj group, and the much smaller number of fossils in the former than in the latter.

Archegosaurus in the Bijori horizon.

I made also a search from Barikondam to the west, at and round the spot where the said *Archegosaurus* was picked up by Major Gowan;[1] but no trace of any fossil was found in the Bijori sandstone.

Shales at Almod and Rorighát.

Fine earthy sandy-micaceous greenish-yellowish shales were observed, as already mentioned, near Almod and Rorighát; except indistinct marks, they were found otherwise unfossiliferous, and they appear to be the same as those mentioned before as immediately underlying the Pachmari sandstone.

Plants between Rorighát and Harapála.

Further to the west, however, on the road from Rorighát to Shápur (by Harapála, Jhuli, &c.), about five miles from this place, I found in a nalla some shales containing plant remains.

[1] Journ. As. Soc., Beng., XXXIII, 1864, pp. 336, 442.

They are dark greenish-grey, rather hard, slightly micaceous. The fossils were not many, but sufficient to indicate the horizon. I collected—

Schizoneura gondwanensis, Fstm. One leaf.

Vertebraria indica, Royle. The more branched thinner form, like that in the Kámthi beds of the Ràniganj group.

Glossopteris leptoneura, Bunb.

Glossopteris, another species.

The fossils of this locality agree therefore with those mentioned before from the Denwa valley, and can be like these considered as on the horizon of the Ràniganj group.

The next observations were of the Damuda rocks and outcropping coal seams in the neighbourhood of Shápur. A full report on this field was published by Mr. Medlicott in 1875;[1] my object was directed to the examination of the outcrops for their fossils.

Shápur coal-field.

In this coal-field also, like in that of Mohpáni, Mr. Medlicott points to the close relation of the coal beds (Barákar group) to the underlying Talchirs (*l. c.*, p. 76), and this conclusion from stratigraphical grounds is perhaps also supported, partly at least, by the few organic remains. These are again plants only, and I think they partly show the existence of representatives of the Karharbári beds, indicating the close connection of these coal beds with the Talchirs.

I first visited the outcrops in the Machna river, north-east of Shápur. The coal crops out at two places; in both some fossils were found which tend to indicate two horizons. The more north-eastern outcrop is close to the village Mardánpur, in the river bed; there are two outcrops running parallel, one on the right and the other on the left bank of the river, but only that on the right bank appears of any importance, and when I was at this place a very primitive kind of mining (digging) was going on on this outcrop.

Mardánpur outcrops.

The dip is 30°, to north-west-by-north. This lower outcrop only was accessible for examination. The whole outcrop (shales included) measures 4 to 5 feet, dipping under white, open and rather coarse-grained sandstones. The coal itself is at this place not thicker than about 2′, being overlaid by coaly shales and underlaid by grey sandy shales, and in the coal itself there is a good deal of what is called fibrous anthracite.

The fossils at this place were very scarce: I found in the coal impressions of *Vertebraria*, and also in the underlying shales some impressions were observed which appeared to me to belong to the same genus.

Fossils.

From these outcrops to the south-west up the river, we find other outcrops at the bend of the river west-south-west of Kotmi. The outcrop here passes from east to west across the river,

Kotmi outcrops.

[1] Rec. Geol. Surv. of India, Vol. VIII.

and is better exposed on the left bank. The strata dip north-east-by-north, at about 15°. The sequence of strata on the left bank is the following (in descending order) :—

a. Uppermost sandstones.

b. Yellowish-brownish-grey sandy shales.

c. Grey earthy-sandy shales with *plants*.

d. A band of very fine earthy carbonaceous brownish-black shales with *plants*. They contain also much pyrites.

e. The coal seam about 2 to 3 feet thick.

f. Shales and sandstones partly already in the river.

On the right bank there appears under these sandstones another bed of carbonaceous shales without coal. Fossils occur in the upper part of both these outcrops.

On the right bank I found in the grey sandy shales—

Glossopteris, fragmentary, and
Nöggerathiopsis (*Hislopi ?*), fragments.

On the left bank were found—

a. In the black shale immediately above the seam—

Glossopteris, fragments.
Gangamopteris and *Nöggerathiopsis*.

b. In the sandy grey shales above—

Equisetaceous stalk.
Glossopteris communis.
Gangamopteris cyclopteroides, Fstm., several specimens.
Nöggerathiopsis hislopi.
Some small seeds (*Carpolithes*).

Here, therefore, were found more fossils than in the Mardánpur outcrops, and they perhaps indicate the horizon of the Karharbári beds.

Temni outcrops.

From here I went to see the outcrops in the Táwa river near Temni (on the map, but by the people called Temru); no fossils were found in the shales, which appeared to me to have a resemblance to Talchir shales; they perhaps represent, as Mr. Medlicott (*l. c.*, p. 80) suggests, the outcrops at Kotmi.

Outcrops in the Suki.

In the outcrops north of Shápur in the Suki river before it falls into the Táwa river, only very few and fragmentary fossils were found. In the lower beds of carbonaceous shales, I found fragments of Equisetaceous stalks and of *Nöggerathiopsis*, and in the upper one a fragment of *Nöggerathiopsis*. The beds dip to north-east-by-north at 10°.

There is no direct indication for a comparison of these outcrops with any of the others, the fossils being so very scarce, except perhaps from the position with the outcrops in the Bhoura naddi (near Sonáda).

About nine miles south-east of Shápur there are other outcrops in the Táwa river near the village of Dolári. Going from Dolári to the river and passing down it to the east, we meet the first (or lowest) seam No. I; it is underlaid by sandstones, and the following rocks are seen—

Dolári outcrops.

a. Brittle, sandy, greenish grey micaceous shales.
b. The coal seam about 2′ thick at this place, the coal, however, brittle and full of the fibrous anthracite.
c. Thin-bedded shaly sandstones.
d. Thin sandstones again up to the next seam.
No fossils were found in this outcrop.

We pass then from here eastwards over sandstones which become thin-bedded and shaly, until carbonaceous shales of 4′—5′ appear, without coal; above these shales some sandstones, and then again dark-grey shales are seen, under which lies the seam No. II, which, however, was then covered; but I saw at Dolári some old heaps of coal, which was said to have been dug from this seam. In the outcropping grey shales some fossils were found, although very fragmentary—

Equisetaceous stalks.
Gangamopteris cyclopteroides, Fstm.
Glossopteris.
Nöggerathiopsis hislopi, Bunb., sp.

These fossils, although very scarce, yet perhaps permit of a comparison of this outcrop with that near Kotmi, and consequently also with the Karharbári beds. Here at Dolári, however, all the outcrops are so close to each other that they may well be considered as representing all the same horizon.

The IIIrd outcrop (to the east) was almost entirely covered by river sand. I procured only with great trouble a piece of coal which was of very inferior quality; but the thickness of the seam could not be ascertained.

The highest and last outcrop, the IVth, to the east, is exposed to some extent. On the underlying sandstones appear thin-bedded carbonaceous micaceous shales. with fragmentary fossils, then the coal seam about 2′ thick (at this place); then shales and sandstones. The only fossils I could observe were fragments of a *Glossopteris.*

As the last to be mentioned are the outcrops about eight miles to the north-west of Shápur in the Bhoura naddi (also Suk-Táwa), close to the village Sonáda. There are several outcrops three quite close to each other in the northerly bend of the river at the village, but they are much concealed, and no fossils could be procured. It would, however, not appear improbable that some of these outcrops at Sonáda represent those in the Suki river north-east of Tekripura.

Outcrops in the Bhoura naddi near Sonáda.

On my return way from Shápur to Itársi (Great Indian Peninsula Railway) I made a search round Kesla in the Denwa group. I think I found the decomposed mottled shales from which *Glossopteris* had been procured; but to my regret failed to find any fossils.

I may now mention that all these sedimentary rocks of the Sátpura coal-basin (south of the Narbada) constitute an unbroken series of beds of the Gondwána system from the Talchirs (the lowest) to the Jabalpur group (the highest), all being generally conformable, or very nearly so. The Jabalpur group, the Bágra-Denwa group, and the Pachmari sandstone form the upper portion of the Gondwána system, while the beds from the shales immediately under the Pachmari sandstones down to the Talchirs constitute the Lower Gondwánas.

The Lower Gondwánas in the Sátpura basin can therefore perhaps be classified thus—

a. The shaly beds immediately below the Pachmari sandstone south of the Mahádeo hill near Almod and Rorighát; soft, earthy and sandy micaceous shales, greenish-yellowish, with indistinct plant remains. They may, as proposed by Mr. Medlicott, well be distinguished as Almod beds.	Probable representatives of the Panchet group.	Panchet sub-division.
b. Mr. Medlicott's Bijori horizon. Sandstones with shales, some of them carbonaceous and fossiliferous.	Represent the Kámthi-Ráníganj group.	Damuda sub-division.
c. Mr. Medlicott's Motúr horizon	Ironstone shales? ...	Ditto.
d. Barákars: some of the coal-beds in the Shápur coal-field.	Barákars	Ditto.
e. Karharbári beds in the Mohpáni coal-field and some of the seams (near Kotmi and Dolári) in the Shápur coal-field.	Karharbári beds ...	Talchir sub-division.
f. Talchir group in the Mohpáni and Shápur coal-field.	Talchir group elsewhere	Ditto.

I may add at end the relations of the several horizons as regards their fossils—

a. Jabalpur group: fossiliferous, plants only, of middle jurassic type (but also *Glossopteris* from the Sher river).

b. Bágra group (H. B. Medlicott): no fossils known at present.

c. Denwa group: a scute of a *Parasuchian* crocodile from near Jhirpa (on the Denwa river) and some plant fragments (*Glossopteris*) from near Kesla.

d. Pachmari sandstone: no fossils known at present.

e. The shales immediately below the Pachmari sandstone: indistinct plant impressions (Almod beds).

f. Bijori horizon: shales with stalk remains: *Equisetaceous* stalks, *Schizoneura*, *Glossopteris*, *Pecopteris*, *&c.*

In the sandstones was found a portion of the skeleton of a reptile said to be *Archegosaurus*.

g. Motúr horizon: no fossils known up to date.

h. Barákars: some plant remains in the Shápur area (*Glossopteris* and *Nög gerathiopsis*).

i. Karharbári beds: in the Mohpáni coal-field and in the Shápur area: *Equisetaceous* stalks, *Gangamopteris, Glossopteris, Nöggerathiopsis.*

k. Talchir beds: no fossils found in this district.

STATISTICS OF COAL IMPORTATIONS INTO INDIA, *by* THEO. W. H. HUGHES, *Geological Survey of India.*

In the leisure of my leave on furlough I have attempted to gather some particulars on the Indian imports of coal and coke, which will, I think, be of interest and perhaps of some little value to those readers of our Records who are concerned about the mineral statistics of India. I had myself so often experienced the want of some readily accessible reference, which should contain in a connected form information on this subject, that I was emboldened to undertake the task of arranging such data as I could bring together, by the knowledge that I should be relieving others of that want. For a large portion of the details here given, more especially those relating to the earlier years, I am indebted to various abstracts and reports published by the Board of Trade and placed at my disposal by Mr. Robert Hunt of the Mining Record Office; for the rest, I have to acknowledge my obligation to Mr. Charles Prinsep of the Statistical Department, India Office.[1]

The annual consumption of fuel for sea-going and river steamers, for railways, for factories, and for other purposes has within the last year or two grown to something between 900,000 and a million tons, and of this amount it may be roughly said that one-half is foreign coal. However much this circumstance is to be regretted by those who are interested in the development of our own fields of supply, there appears to me to be small chance of a diminution in the ordinary rate of importation until native coal is lightened to some extent of the heavy burden of charges imposed by land carriage and by freights, so that it may compete on more favorable terms than at present with its rivals at the western ports of the Bombay Presidency, and those of Madras and Burmah. Our three principal coal mining districts, Ránigauj, Karharbári, and the Wardha valley, are so situated that the item of railway transport alone—even in the case of the two more favourably situated fields, the Ránigaunj and the Karharbári—trebles and quadruples the actual costs of the coal by the time it reaches a port for shipment; and it utterly prohibits the sale of the produce of the Warora colliery (Wardha valley) within a distance of 200 miles of Bombay.

Beginning with the year 1853, the shipments of coal and coke to India were 43,562 tons. Since then, after the lapse of a quarter of a century, they have risen to 609,735 tons. The ratio of increase has not been by any means steady: wars,

[1] Without Mr. Prinsep's assistance I should have found my undertaking a more tedious affair than I at first imagined it. The labor involved in dealing with figures is very inadequately represented by the printed space they occupy.

rumours of wars, famines, and improved home freights have always exercised an irregular influence ; as during the past two years, the importation having jumped from 399,887 tons in 1876 to 539,533 tons in 1877, and to 609,735 tons in 1878. Had not disturbing causes, such as the Madras famine and the anticipations of war, been at work in 1877, it is probable that the imports of coal for that year would not have amounted to more than 420,000 tons; and under peaceful conditions, the figures for 1878 would have been considerably less than they actually were. Our main supply of foreign coal has hitherto been derived from the United Kingdom, the contributions furnished by other countries, with the exception of Australia and France during spasmodic periods, being insignificant. The tonnage of imports for all India, from all countries, commencing with the year 1853, is as follows :—

TABLE I.—*Imports of coal and coke to India from 1853 to 1878.*

Years ending 30th April	1853	Coal and Coke	...	43,562
	1854	"	...	58,410
	1855	"	...	41,987
	1856	"	...	76,712
	1857	"	...	82,078
	1858	"	...	92,983
	1859	"	...	99,701
	1860	"	...	74,263 *a*.
	1861	"	...	...
	1862	"	...	174,862 *b*.
	1863	"	...	122,722
	1864	"	...	189,611
	1865	"	...	216,985
	1866	"	...	228,319
Years ending 31st March	1867	"	...	257,652 *c*.
	1868	Coal	... 368,618	385,331
		Coke	... 16,713	
	1869	Coal	... 332,718	348,926
		Coke	... 16,208	
	1870	Coal	... 315,935	337,023
		Coke	... 21,088	
	1871	Coal	... 269,396	286,180
		Coke	... 16,784	
	1872	Coal	... 361,960	374,184
		Coke	... 12,224	
	1873	Coal	... 310,265	324,643
		Coke	... 14,378	
	1874	Coal	... 354,231	359,903
		Coke	... 5,672	
	1875	Coal	... 360 251	366,539
		Coke	... 6,288	
	1876	Coal	... 389,480	399,887
		Coke	... 10,407	
	1877	Coal	... 523,384	539,533
		Coke	.. 16,149	
	1878	Coal	... 603,904	609,735
		Coke	... 5,831	

(*a*) The returns are qualified by the statement "as far as can be stated."

(*b*) For this year the returns are not complete for Bengal.

(*c*) For eleven months only.

In the following table the quota of *coals* annually supplied by each country is given for the years 1870 to 1874 inclusive, but for the succeeding periods to 1877, I have only noted the larger contributions. It will be understood that under the head of Holland, Mauritius, Red Sea, Aden, Ceylon, and the Straits, it is "transit coal" and not "indigenous coal" that has been exported for India:—

TABLE II.—*Imports of coal to India from various countries from* 1870 *to* 1877.

	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
United Kingdom...	301,864	257,914	348,725	287,818	330,635	339,821	359,680	494,318
Australia ...	12,607	8,942	5,917	1,511	14,677	4,652	6,130	798
France ...	415	1,241	454	17,902	5,676	...	156	1,111
Germany ...	10	250	5,007	1,613	1,710	660	...	500
Mediterranean ports	...	...	...	...	275	...	...	...
Holland ...	...	...	102	...	...	...	...	...
Russia ...	...	500	...	...	...	...	...	...
America ...	460	...	...	441	799	687	130	2,146
Mauritius ...	...	103	...	...	...	...	...	...
Red Sea ...	...	...	...	...	50	...	...	...
Aden ...	...	120	187	136	98	...	...	...
Ceylon ...	420	363	1,886	218	207	...	...	...
Straits ...	...	...	...	187	74	...	...	...
Java	...	...	...	400	...	...	802	400
Other countries ...	159	188	182	44	30	...	...	...
Total ...	315,935	269,396	361,960	310,265	354,231	...	...	...

During the last year, the shipments of Australian coal have fallen off seriously; and I think we have now seen almost the last attempt to force it into the Indian market. For the sake of reference, I give the imports for the 20 years ended 1877:—

TABLE III.—*Imports of Australian coal to India from* 1857 *to* 1877.

	Tons.		Tons.
1857 to Bengal	... 2,271	to Bombay	... 2,176
1858	... 14,061		... 8,998
1859	... 4,278		... 2,293

TABLE III.—*Imports of Australian coal to India from* 1857 *to* 1877.—contd.

		Tons.			Tons.
1860 to Bengal	...	10,008	to Bombay	...	8,112
1861 (*a*).	...	...		...	12,045
1862	...	7,191		...	5,649
1863	...	...			
1864	...	13,292			
1865	...	5,207			
1866	...	6,376			
1867	...	7,465			
1868	...	5,792			
1869	...	9,257			
1870	...	12,607			
1871	...	8,942			
1872	...	5,916			
1873	...	1,511			
1874	...	14,677			
1875	...	4,652			
1876	...	6,130			
1877	...	798			

(*a*). Returns for Bengal not given for 1861.

To illustrate the distribution of the imports to the five great Provinces of India, I have selected the years from 1870. Bombay is by far the largest receiver; the cotton-mills of the city of Bombay and the railways having their terminuses there being heavy consumers of foreign coal. In Bengal the railways and nearly all the steam-mills burn exclusively the produce of the better seams of the Rániganj field and those of the Karharbári field :—

TABLE IV.—*Imports of coal to different Provinces of ndia from* 1870 *to* 1877.

	1870.	1871.	1872.	1873.	1874.	1875	1876.	1877.
	Tons.	Tons	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Bombay ...	239,651	167,257	220,884	208,269	216,543	249,836	260,080	368,937
Bengal ...	42,443	63,929	89,775	48,688	82,120	63,821	61,091	76,278
Burmah ...	20,198	26,731	39,981	36,715	27,071	33,301	38,397	47,770
Madras ...	11,648	9,053	9,390	15,513	25,043	12,155	20,275	22,544
Sind ...	1,995	2,426	1,930	1,079	3,454	1,138	9,637	7,855
Total ...	315,935	269,395	361,960	310,264	354,231	360,251	389,480	523,384

Though Aden and Ceylon do not come within the official limits of India, I. append the few following statistics for comparison:—

TABLE V.—*Imports of coal to Aden and Ceylon from* 1866 *to* 1876.

	1866.	1867.	1868.	1869.	1870	1871.	1872.	1873.	1874.	1875.	1876.
ADEN—											
Coal ...	70,361	115,572	106,265	62,610	67,546	87,394	85,158	75,569	?	74,797	99,423
Patent fuel	17,713	5,630	10,462	15,027	18,318	13,434	11,968	13,106	?	3,486	5,951
CEYLON—											
Coal ...	63,174	86,206	67,589	?	?	107,625	62,555	76,132	?	74,083	81,789
Patent fuel	8,579	2,702	9,647	4,412	14,446	11,436	6,076	4,769	?	...	...

Patent fuel figures to some extent amongst the imports to Madras and Bombay, but the amounts of late years have been quite insignificant.

LONDON, *December* 1878.

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GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1879. [May.

NOTE ON THE MOHPÁNI COAL-FIELD, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

No ground in India has been so frequently noticed in these pages as the Mohpáni coal-field,[1] situated on the south side of the Narbada valley, 95 miles by rail below (west-south-west of) Jabalpur, and at the northern edge the Sátpura basin of the Gondwána rocks. It owes this distinction to three circumstances: first, to its position, close to one of the great trunk lines of railway, and as the nearest open source of coal to north-western India; its distance from Allahabad is 322 miles, or 83 miles nearer than the Karharbári field, from which all the coal for the line up to Delhi and Lahore is at present drawn;[2] and its distance from Kandwa, the junction of the Indore and Neemuch line, is 196 miles, or 122 miles nearer than the Warora colliery to the same point.

The second circumstance which gives importance to Mohpáni is, that it is the only easily accessible coal-field in this region. It has been known from the first that the only outcrop of the coal-measures along the northern edge of the Sátpura basin is at Mohpáni; and the failure of the boring experiments made during the past four years, under orders of Government, and of which an account has been published in the papers referred to above, has fairly established that the coal is not within easy reach at any other point along that line—a conclusion which indirectly gives an indefinitely increased value to the Mohpáni field.

The third circumstance which has brought Mohpáni so frequently under official notice is, the possibly precarious nature of the supply in that field. The long protracted doubt on this point has been entirely owing to the timorous and

[1] Mem. G. S. I., Vol. II, Pt. 2, 1859; Vol. X, Pt. 1, 1873. Rec. G. S. I., Vol. III, Pt. 3, 1870; Vol. IV, Pt. 3, 1871; Vol. V, Pt. 4, 1872; Vol. VIII, Pt. 3, 1875.

[2] The opening of the Palamow fields, *by the most direct line*, would remove this advantage.

inefficient management of the mining operations, especially for works of exploration, by the Narbada Coal Company, within whose property the known field lies. The mines were started at or close to the outcrop in the Sitariva river and within a short distance, in both directions, the coal was found to be cut out against two intersecting planes of faulting, the calculable amount of coal being, of course, limited to what lay in the small triangular area between these planes and the outcrop. There never was any reasonable doubt that the coal did occur outside these faults in one or other direction, or in both; and confidence in the resources of the field was sufficient to guarantee the construction of a full-gauge branch railway, 13 miles long, from Gádarwára to the pits; still, as time wore on, the urgency of proving the extent of the field became more and more pressing, so as at least to be prepared to break fresh ground before the original small block of coal-measures became exhausted.

There were two directions for these explorations: one to the south-east, to the dip of the measures, towards the main area of the basin; the other to the north-east, on the local strike of the measures. The objections to the latter ground were, that the disturbance of the rocks, already a sufficient difficulty in the existing workings, was known to be indefinitely greater to the north; and, that being also the direction of the edge of the basin, there was an extra presumable risk of original banking out of the seams. The fear in the other direction was that the measures might be let down to an inaccessible depth; but of this opinion there was no confirmation in the outcrops, which are fairly exposed in the bed of the river. These considerations were repeatedly, but ineffectually, urged upon the mining administration. The ground to the north-east was superficially the easier to explore, and efforts were chiefly spent upon it, but without the smallest success. Borings were also attempted to the south, and even a new shaft begun in that direction; but in no case was the trial carried far enough to touch the coal, even at the depth calculated from the dips, without any allowance for possible small downthrow.

When I visited the field in December 1876, in company with Mr. Hughes, the uncertainty was still pending, no advance having been made with the exploration, and the original block of measures was being rapidly worked out. The trials in other parts of the Sátpura basin were then in progress, but hopes of success were waning, and altogether the prospects of mining enterprise in this part of India seemed at its lowest ebb. When in October 1878 the last experimental trial outside the Mohpáni field had failed to prove coal, the necessity for a proper exploration of the ground within that field became imperative. To urge this point, and to see what had been done since the close of 1876, I visited the collieries in March of this year.

It was said above that there never had been any valid doubt upon the extension of the seams to the south-east; that there was no evidence for the supposition of a great fault, throwing the measures down out of reach on that side; still, until the ground was proved, anxiety could not be altogether allayed. In 1870 (see Recs. Geol. Surv. India, Vol. III, p. 69), I pointed out that "the best means of immediately testing the southern extension of the measures is from shaft No. 2," which had been long since abandoned on account

of the influx of water when the coal was reached. In December 1876 an attempt was being made to fix pumping gear in this shaft; and the new manager, Mr. J. A. Maughan, M. E., who took charge of the mines at the beginning of 1877, seems to have pushed on this work with vigour, for on the occasion of my recent visit, in March last, I found that all the coal that was then being raised was by this shaft, from workings to the south, extending to about 350 feet from the shaft, beneath the covering Mahádeva rocks, and quite beyond the presumable position of any great east-west fault. In these new workings the main (30′) seam is in full force, and also the lower seam.

Thus whatever apprehension may have existed regarding the supply of coal in this field may be laid aside. The condition of the seams in the new ground opened by Mr. Maughan gives every reasonable expectation of an abundant supply, within a moderate depth from the surface.

Still the difficulties of the enterprise are not at an end. The evil effects of protracted neglect of system and forethought are not to be overcome in a moment; and the output of the colliery cannot be counted upon with any certainty until those defects are removed, and a proper system of mining established. As has been already stated, all the old openings, shaft No. 2 amongst them, are at or near the outcrop of the seams, so that the coal lies chiefly at a lower level than in the shaft; and the dip of the seam being still considerable and variable, the difficulties of raising the coal and of draining the mine increase rapidly as the work advances. Until a new shaft is in working order well to the deep of all the present openings, a large and regular output of coal cannot be depended upon.

Notice may here be given of the concluding operations in search for coal outside the Mohpáni field, in continuation of that given in the Annual Report for 1877 (Rec. Geol. Surv. Ind., vol. XI, p. 7). The Anjan boring, mentioned as then in progress, was carried to a depth of 350 feet (11th May 1878) without piercing the covering red rocks of the Mahádeva series. This was the last trial to find the coal-measures in proximity to the detached inliers of the Talchirs.

There remained but one position favorable for a trial, and where, I must confess, I looked with very great hopes for success. It is close to the south-east of the village of Baner, or Benár, at the very edge of the Narbada Company's land, in ground formerly held by the Sitariva Coal Company, when a shaft had been begun, by my advice, at this spot.[1] It is less than half a mile from the seams in the Sitariva; an outcrop of coal-measure sandstone (or a rock undistinguishable from it) occurs north of the village, and the shaft begins in the red covering rock, so that unless the coal dies out within that short distance, or some undetected unconformity occurs between the formations, there seemed a certainty of striking the coal here, and I recommended to Government that a boring should be put down in continuation of the old shaft.

This boring commenced on the 24th February 1878, the water and mud having been cleared from the shaft, which was found to be 118 feet deep,

[1] See Rec. Geol. Surv. Ind., Vol. IV, p. 68.

and the bottom 13 feet, which was not walled, consisted of purple clay, brittle and falling off in flakes. At 179 feet the red rocks were passed through. The dip and the distances from the boundary not being accurately known, on account of the covered nature of the ground, no exact calculation could be made; and in such massively-bedded rocks any such calculation could only be approximate; but at a probable estimate of a dip of 20° and a horizontal distance of 500 feet, this proved depth and thickness of the Mahádeva rocks is about what should occur under the assumed condition of conformity; and at least it proves that between this spot and the boundary there can be no great post-Mahádeva fault, with southerly downthrow.

At 179 feet the boring entered on sandstone, grey and white, felspathic, most like the coal-measure rock; and our hopes were very strong that coal would soon be struck, as, in the supposed normal section, it all lies within the top 150 feet of the measures. Carbonaceous shale and even fragments of coal appeared in some of the samples, but only to delude our hopes, for the boring was continued to a depth of 426 feet, or 247 through the lower formation, without any better result, so I recommended the work to be stopped.

In attempting to account for this section, several conjectures are apparent. It may be that the carbonaceous measures passed through are not the true coal-measures, but only the carbonaceous measures of the middle Mahádeva horizon, such as were found at Tundni, eight miles to the west; but the total absence of such beds in the clear section in the Sitariva, within half a mile of the boring, makes this supposition the least probable. There is then the possibility that within this short distance the coal seams may have died out; this is the most unfavourable view of the case, and one that seemed unlikely, considering the great regularity of the bottom seam in the lower mine, north of the river; but it is a chance that must not be lost sight of in our Indian coal-fields, especially in these lower measures; indeed, in this same bottom seam, I have observed something very like an original extinction, in the section of the "new incline," where the coal passes rapidly into a sandy shale, never having come to the surface on the rise of the little hill. A third supposition is, that the boring chanced upon a band of disturbance, and so passed down between the broken and displaced seams. The mixed nature of the samples at and below a depth of 325 feet gave some support to this supposition, and it was the one I felt inclined to adopt.

The facts disclosed by the new working at the mines dispose me, however, to think that we have here to deal with original features of the deposits. The lie of the seams south of shaft No. 2 is not quite what would be inferred from the outcrops: the strike is more nearly due south; and in rising to the west the coal is stopped out against a steeper sloping face of sandstone. Mr. Maughan has had to deal with many slips and crushing of the seams in these new workings, but they have all proved only temporary obstructions, save this one on the west. To prove it thoroughly he had a boring put down from the surface at a point about 200 feet west of this stoppage. At 140 feet the red rocks were passed through; here again, as at Baner, this depth indicating the general conformity of the groups. Below 140 feet the bore passed through 270 feet of coal-

measure rocks, "grey post and blue metal," *i., e.*, sandstone and dark clay, to the total depth of 410 feet, without a sign of coal. We can hardly again have recourse to the conjecture of a space between faulted ends of the seams. The one supposition that meets all the local facts is that of original limitation.

I said above that this is the least favourable view to take, as of course if the interruption were only due to faulting, the recurrence of the seams could be counted on, whereas no diagnosis of the ground can do more than guess at variations of original distribution. I do not think, however, that there need be any alarm on this score for the immediate, or even for the distant future. I cannot but think that there must be a great store of coal beneath the Malpi (Mulpee) plain, and south of it up the valley of the Sitariva.

ON PYROLUSITE WITH PSILOMELANE OCCURRING AT GOSALPUR, JABALPUR DISTRICT, *by* F. R. MALLET, F. G. S., *Geological Survey of India.*

The existence of manganese ore at Gosalpur appears to have been known for a long time past, and the mineral has been in use to some little extent amongst native glass makers in the neighbourhood. It was first brought to the notice of Government by Mr. W. G. Olpherts in 1875, to whom we are indebted for specimens subsequently received. Lately, the Deputy Commissioner, Colonel Playfair, has again called attention to this ore and asked for information regarding it. Within the last month Mr. Medlicott has visited the locality, and reports upon the deposit as follows:—

"The sections available for examination were very poor indeed, only shallow holes, 5 or 6 feet deep, along an irregular line some 20 yards in length, on the outskirts of the village of Gosalpur, at the base of the low ridge on which the dák bungalow stands. The well in the village, from which also the ore was obtained, is at a slightly lower level, about 120 yards nearly due east of the shallow pits, but it was not available for examination. I have, however, satisfied myself that the deposit is not a vein or lode, and that it has no apparent connection with any vein or lode in the underlying transition rocks. It is not, either, a layer or bed in the formation in which it occurs, which is laterite, but is irregularly distributed throughout this rock in lumps of various shapes and sizes. These mostly have a spongy or cellular structure, but some pieces of very compact ore, more or less reniform, were found. This laterite is of the older type: at least in the exposed sections I could not detect any palpable debris, which generally characterizes the secondary or detrital laterite. It is therefore presumable that the lumps of ore are innate, and that the manganese is an integral component of the laterite in this position. The ore in the little pits is at a higher level than in the well, which is still in laterite at the water level, 45 feet from the surface, and where the ore seems to occur at any level. It is, I think, reasonable to conjecture some local source for such an unusual ingredient in so wide spread a rock as the laterite; but the underlying rocks are greatly concealed by the laterite itself, or by alluvium, and no vein of this mineral may be found in the

few exposed outcrops: manganiferous iron ore is, however, known to occur in these rocks, more to the north at Mogála and Jauli.

"Although the nature of the deposit is thus more or less obscure, I see no reason to doubt that a large supply of this ore may be depended on at Gosalpur."

The ore is dark steel gray, finely crystalline, pyrolusite, mixed with a varying proportion of psilomelane. Some lumps are almost free from the latter mineral, others contain a considerable amount; but on the whole the psilomelane is very subordinate to the pyrolusite. The exterior of the lumps, and the surfaces of most of the internal cavities are more or less coated by oxide of iron.

A carefully selected average sample of the ore yielded on analysis—

{ Manganese calculated as protosesquioxide	75·86
{ Oxygen	9·96
Iron, sesquioxide (with trace of alumina)	4·53
Baryta	3·55
Phosphoric acid	·28
Insoluble in hydrochloric acid	2·74
Combined water	2·41
Hygroscopic water	·28
	99·61

The ore contains 54·66 per cent of manganese, and 3·17 of iron, with ·28 of phosphoric acid and no sulphuric acid. It contains 15·26 per cent of available oxygen = 83·00 per cent of peroxide; as an oxidizing agent, therefore, it is of high value, the average run of manganese ores met with in commerce containing only 60 to 75 per cent. The percentage of peroxide in the ore, calculating all the manganese as peroxide, would be 86·42 per cent., but the presence of some psilomelane reduces the available percentage about $3\frac{1}{2}$ per cent. The insoluble residue is chiefly, or entirely, silica. With reference to the presence of baryta, a substance so commonly met with in psilomelane, and not unfrequently in pyrolusite, it may be mentioned that baryta in the form of barite occurs in some quantity at Imlia near Sleemanabad, 20 miles north-east of Gosalpur.

A GEOLOGICAL RECONNOISSANCE FROM THE INDUS AT KUSHALGARH TO THE KURRAM AT THAL ON THE AFFGHAN FRONTIER, *by* A. B. WYNNE, F.G.S, &c., *Geol. Surv. Ind.*

In volume X. of the Records, I gave a sketch of the distribution of the tertiary rocks in the N.-W. Punjab.[1] In that account, and in the map accompanying it, the ground immediately along the Affridi frontier is omitted. In order

[1] The information given regarding Upper Punjab geology, by the Geological Survey, being somewhat scattered, I may mention that the most important areas as yet examined will be found referred to, besides the above, in Memoirs Geol. Sur., Vol. XI, pt. 2 (Trans-Indus Salt Region), also Qrtly. Jnl., Geol. Soc., Lond., Vol. XXX, p. 61, and Vol. XXXVI, p. 347; a memoir on the Salt Range, Mems. Geol. Surv. Ind., Vol. XIV. On the neighbourhood of Murree, Records, Vol. V, pt. 1, and Vol. VII, pt. 2. On Jamú hills, Records, Vol. IX, pp. 49 and 155. On part of Upper Punjab, Records, Vol. VI, pt. 3. On Kharian hills, Records, Vol. VIII, p. 48. On Sirban, Memoirs, Vol. IX, pt. 2.

to fill this gap, as far as possible, taking advantage this season (1879) of my camp being on the frontier, after visiting the continuation of the Salt Range beyond the Indus, I carried observations as far as Thal. Owing chiefly to circumstances connected with the present Affghan campaign this country, always more or less subject to frontier difficulties, presented others regarding scarcity of supplies, necessitating a rapid inspection of the ground.

The whole of the country immediately to the east and south is within the limits of the great fringing belt of tertiary rocks which borders, where it does not form, the outer hills of the Western Himalayan area (taking this in its extended sense to include all the most northerly Cis-Affghan mountains of the Punjab). These tertiary rocks of the neighbourhood embrace the upper and lower Siwalik sub-divisions of the newer mechanically formed beds, and also very extensively the underlying older tertiary "Murree group," and the eocene (Subáthu) limestones; the two last passing into each other by alternation, and the limestones becoming largely developed westwards in the Kohát salt field.

The whole route from Kushálgarh to Thal lies in the Subáthu zone, for 93 miles. Cis-Indus, all along the northern margin of the Ráwalpindi plateau, the country is traversed by what I have called the abnormal junction feature, forming the inner boundary of the outer tertiary zone; it is coincident with the base of the first high hills rising to the northwards; but further west, trans-Indus, though the same physical relations continue, of lofty limestone mountains, comprising various mesozoic and eocene groups, bordered to the south by inferior hills of tertiary age, this junction feature has not been examined, because the higher mountains at the base of which it should occur are all but entirely occupied by the wild Affridis, Zhúwakkis, Akhor Kheyls, Urukzais and other *Yagi*, or independent tribes, whose country is closed to Europeans by British authority, as strictly as Chinese Tibet is by the officials of that region. Discordance of one kind or another is the strongest characteristic of this junction feature, by some regarded as a line of fracture, by others as an unconformity marking a limit of deposition, traceable from the N.-W. Punjab to the Simla area of the Himalayas, possibly much further, and analogous to a very similar feature in the structure of the outer Alps. It dates from the Himalayan mountain-forming disturbance, posterior to earliest eocene times; and it is remarkable that, although some appearance of a transition from the older nummulitic limestone masses north of the line into the newer and more markedly nummulitic beds to the south has been observed, these newer beds have been but doubtfully distinguished north of the junction in the Upper Punjab. The weight of evidence, such as it is, goes to show that the upper nummulitics ranging south of the junction were, if at all, but sparingly deposited and capriciously distributed over the region to the north; nor is it at all certain that the nummulitic beds north of the junction may not be but a local development of older eocene limestones along the inner (northern) side of the tertiary zone.

Kushálgarh, where the Indus is now crossed by a bridge of boats, is the locality given for some mammalian bones and teeth, formerly miscalled the Attock fossils, which present certain differences from Siwalik forms, as pointed out by Mr. Lydekker in these Records, Vol. IX, pt. 3, Pal. Ind. Series X. 2. The

exact place whence these fossils were procured is unknown, and several efforts to rediscover it have failed.[1]

The rocks of the neighbourhood are on the horizon of the lowest Siwalik or uppermost Murree beds, here quite impossible to separate by any distinctive petrological character, a difficulty increased by the scarcity of fossils of any kind. The existence of fossil timber, however, which is found in the lowest of these groups, though not always present, may indicate the rocks belonging to the older group of the two.

The ground, though open, is ridgy and rugged; the beds are highly inclined to the north or vertical, and run in directions from E. and W., to N. E.—S. W.: they include soft and harder greenish and gray sandstones with red, purple, and occasionally gray, alternating clays. For several miles westward of the Indus, its characteristic gneiss and metamorphic pebbles are thinly scattered over the country; but I was unable to find a single erratic, *i. e.*, travelled block or boulder such as are so numerous across the river about Jand, &c.

Eight miles to the northwards are hills of nummulitic, limestones of the Subáthu character, bent up in compressed folds, and associated with dark shales, red clays and gypseous masses. Sulphur and petroleum springs occur, closely connected with the upper zones of these limestones and clays, as on the right bank of the Indus, near Dandi hill-station (where there are appearances of once extensive sulphur or alum works), or issuing from the solid limestone in the Ungo pass.

About the same distance still further northward, the main inner boundary of the Murree and Subáthu zones is over-slipped by the hill nummulitic limestone of Nilábgásh mountain, which rises immediately north of the abnormal junction feature, and includes amongst its beds jurassic, if not other secondary rocks.

Westward of the ground intervening between this and Kushálgarh, the country is apparently complicated, alternations of the limestones with red rocks of Murree aspect, displaying themselves largely in the southern part of the Zhúwakki Affrídi hills.

From Kushálgarh westward the general surface rises towards the commanding hill of Gurgurlot, the summit of a range which, with the exception of rock salt, repeats all the essential points of structure observed in the ridges of the Kohát salt field.

Approaching this hill, the purple and red rocks show much contortion, and fold round the greatly disturbed double anticlinal curvature which occupies the range, but so misshapen, crushed and twisted that the original simplicity of structure is greatly obscured. The axis of these folds run from N.-E. through S.-W. to a westerly strike. Just north of the Gumbat pass another ridge of nummulitic limestone includes, between itself and Gurgurlot, a set of the dark purple and red sandstone and clay beds of the Murree group, as a synclinal

[1] Bones seem to be specially uncommon among the beds of Kushálgarh, perhaps all the more reason for their occurrence in numbers in some local layer. Such a situation is said to have been found several years ago, 3 miles west of the village, in a cutting for the Kohát road, near a *búrj* or watch-tower.

fold. The very lowest of these, at their contact with the last-mentioned limestone, contain bones. Rib bones and fragments only were found, but unfortunately no teeth. The occurrence of these so low in the series shows, however, that the bone beds of the Punjab are by no means limited to the upper (or Siwalik) groups.

It is on the southern side of the Gurgurlot range, at Koteyri, that an extraordinary example of complete inversion occurs, placing the eocene limestone for a width of more than a furlong above the next newer group of sandstones and clays (see Trans Indus Salt Region, Mem., Geol. Sur., Ind., Vol. XI, pt. 2, p. 20.)

Besides the ordinary succession of the salt region tertiary beds, bands of flaggy limestone here appear in the gypsum, having the curious structure called cone-in-cone, very perfectly developed.

The general succession observed in and near the Gurgurlot range is as follows (in natural order) :—

Lower Siwalik	5 Soft greenish-gray sandstones, with bones, and red clays; the sandstones sometimes conspicuously massed together.
Murree beds	4 Purple sandstones and bright red or purple clays.
Eocene Sabáthu	3 Alveolina and other fossiliferous limestones.
	2 Red clay zones of the Salt Region to the south.
	1 Gypsum in massive beds and masses, with layers of dark flaggy limestone and dark grayish clays.

Some of the springs on the southern side of Gurgurlot are said to be saline, more so at times than at others. The range declines to the westward, being connected by lower limestone ridges with the higher ones of the Bangásh hills. Both the latter and the low ridges mentioned expose here and there, interstratified with the limestones, clay and sandstone bands, having entirely the ordinary aspect of the Murree beds, but sometimes including coarse sandy calcareous layers enclosing nummulites, or bands of olive clay. An alternation of this kind is seen at the little pass on the Kohát road north of Lachi.

In the neighbourhood of Gumbat the low ground seems to have been eroded chiefly, if not entirely, from the sandstones and clays of this part of the lower tertiary rocks; and in every escarpment of the surrounding country, the red rocks are seen to underlie the limestone portion of the ridges. This appearance is as strongly seen as anywhere along the northern side of the Gurgurlot ranges; yet when followed eastward through the Gumbat pass, these red rocks are plainly resting upon the limestones.

Accepting this as the normal order, it would be easy notwithstanding appearances to suppose the limestone in all cases, or nearly all, the oldest rock. But further west this is found not to be the case, several alternations of the limestones and sandstones of different thicknesses taking place; so that it becomes exceedingly difficult to find the true positions of these limestones and red rocks where the sections are isolated or much contorted.

From Gumbat to Kohát the road passes for 8 miles through an open earthy or stony country of alluvial flats, terraces, and undulations exposing either the lower tertiary sandstone and clays, or limestones; the Gurgurlot range lies to the south, and the rugged hills of Zhúwakki land are approached to the north, showing long edges of limestone cropping out above the red Murree-like rocks.

Nearer to Kohát, about Billotang, low barren limestone hills are entered, showing many undulations of the beds at all angles up to vertical, and several of these again exhibit the same alternation of the limestone, sandstone and red clays. A low ridge from these hills stretches towards Kohát, in front of the lofty and highly contorted or partially scarped limestone mountains of the Affrídis, crossed by the hired pass from this country to Peshawur.

The remainder of the distance to Kohát (15 miles from Gumbat) is through flat irrigated country; but in the ascent from the station to the pass just mentioned, dark arenaceous and rusty impure limestones, containing jurassic and cretaceous fossils, are folded amongst the dark gray nummulitic limestones of the hill type; and the line of abnormal junction traverses the country from east to west along the southern face of the Affrídi hills. Further north, within the pass, much of the gray limestone everywhere visible may be of triassic or at least mesozoic age; a sufficiently close examination to decide this was prevented by political reasons at the time I traversed the pass.

At Kohát one is close to the frontier, the much folded and contorted limestone wall of the Affrídi mountains, rising abruptly from the northern side of the Bangásh, or Kohát Towey, valley and attaining greater elevation as the mountains run westward. The station is built upon a stony rising ground, one of the many fan-like accumulations of subaerial detritus at the mouths of the mountainous valleys of the Upper Punjab[1]. The situation, the vicinity of a mass of limestone mountains, and the presence of coarse stony superficial deposits, are all favorable towards the existence of the remarkable springs which occur here; a large one, over which a musjíd has been built, sends forth a perpetual great stream sufficient to turn the wheels of several mills, and to water the whole station. Looking towards the Bangásh valley, famous for its fruit trees, its limpid streams, and the cutting cold wind which blows down it on winter mornings, the high mountains lie to the north, and a long ridge, also of limestome, terminating eastward in considerable rugged eminences, closes it in on the south. This southern ridge is of fossiliferous upper nummulitic limestone, overlying a thick band of such gray sandstones and red clays as are common in the Murree group, the whole dipping rather steeply to the south. The only spot at which the northern limestones could be inspected was near a group of ruins, some 4 miles from the station, perched nearly on the top of a minor spur. The limestones here were found to contain dark and rusty beds distinguishable even from the road, amongst which *Belemnites* and fragments of other cretaceous *Cephalopoda* (as determined by Dr. Waagen) were observed. The beds as usual appeared to be folded, but from a distance the whole face of the mountains presents sufficient of a northerly dip to give them a decidedly scarped appearance. Here also were found the ordinary features of the line of abnormal junction: on one side nummulitic limestones interstratified with red beds of the older tertiary aspect, and on the other, different hard limestones, including bands containing jurassic

[1] Finely displayed, I am told, along the upper waters of the Kurram river in Afghanistan, as seen from the Peiwar Kotul route.

and cretaceous fossils, the beds dipping diversely and presenting the appearance of fractured displacement.

The valley is narrow, scarcely a mile in width, the frontier line sometimes not more than half that distance from the road, and the surface is formed of a drab saline clay soil or alluvium, apt to harden at first on drying, then to pulverise into fine dust, and to form rapidly deep fluid mud on the access of rain. Near the village of Kuz-Usturzai,[1] the main stream is joined by another from the valley of Samilzai and Murrai, which re-enters the mass of the mountains to the northward for some 8 or 10 miles, and might therefore be likely to expose something of their geological relation. As is not unusual along the frontier, this recess containing some cultivable ground, is included within the British boundary, the "red line" leaving the mountains outside; still it was considered expedient that I should not enter the valley without an increased guard and special arrangements, which the pressure of circumstances precluded. So far as could be seen, the ground within it was traversed by low limestone ridges, partly continuous with, and partly repeating, the features of the adjacent part of the main valley, where nothing except eocene beds were recognized. On the north-eastern and northern sides of this Murrai valley, the lofty limestone escarpment from the neighbourhood of Kohât was observed to sweep along, broken by ravines and plateau-like summits, towards Khuyukkai Sir, culminating some miles to the westward at the tabular summits of Mazzeoghar and Dupah Sir,—the latter over 8,000 feet in height, faced to the south by stupendous cliffs, and overlooking the high valley of Tirah to the north.

In these cliffs strong zones of gray limestone, alternating with much softer thick bands, probably of shale, could be seen dipping at angles of 30° and 40° in northerly directions, the dip becoming more marked and steeper in the same direction, away to the westward. The stream coming from these mountains brings down pebbles chiefly of dark gray limestone in which fossils are concealed or absent, but the rock looks and smells like the hill variety of the nummulitic limestone; there are also a few of light-coloured fossiliferous nummulitic limestone, others of a greenish semi-oolitic limestone, containing parts of bivalve shells with strongly marked umbones and many large blocks of hard white quartzite sandstone.

The road to Hangu rises from the alluvium of this stream on to flat-topped *Karewah* hills, formed of horizontal boulder conglomerates, from 40 to 100 feet thick, beneath which are vertical grayish dull sandstones and bright red clays. These last are seen again edging the bases of long low nummulitic ridges to the northward, which dip into the valley in various northerly directions. It here becomes evident that the Hangu valley is excavated upon the softer much disturbed red clays and sandstones underlying and interstratified with thick zones of the Alveolina and other upper nummulitic limestone, the whole arrangement being not unlike that of the Subâthu beds in many places along the north of the Râwalpindi plateau, but on a much larger scale. Deep excavation in the valley beds and the stony hills they form continue to the camping ground of Sherkot, 12 miles from Kohât, and there is nothing in the structure of the ground within British territory here to mark the westerly continuation of the discordance

[1] Commonly called "Sthoorzee" by the natives.

between the nummulitic beds of the vicinity and the limestones of the mountains to the north.

In the next march, to Ibrahimzai (8 miles), another stream from the northern hills, having a long easterly course from behind the Samána ridge, is crossed at Raiss; the boulders in the stream being of similar kinds to those previously mentioned. The valley here becomes much more confined and hilly, and at the fifteenth mile from Kohát is obliquely crossed by the ridge which has hitherto bordered it on the south, the river finding its way through a deep gap called Khwajahkhezal. In the ascent to where the road is led through this pass, on the northern bank of the stream, as in some hills to the eastward, the more solid limestone of the ridges is seen to overlie compact lumpy gray or drab Alveolina limestone, which rests upon strong gray sandstones immediately overlying thick red clays; the whole folded into an anticlinal and synclinal curvature. From the top of the pass to its western opening, an ascending series with a dip of 50° or 60° is exposed, thus—

Upper nummulitic.	Red clays; remains of a band several feet thick.	
	Strong nummulitic limestones, overlying ...	234′
	Greenish shaly and softer beds, concealed by talus ...	219′
	Red clays.	Obscured.
	Thick alternations of strong bedded and shaly limestone and greenish shales; layers of the limestone crowded with fossils	258′
	Grayish and purplish sandstones with red clays ...	over 100′
		811′

Westward of the pass the valley again slightly opens, and on its south side higher beds of the limestone, overlying red clays, &c., with a southerly dip, form a ridge extending nearly to Ibrahimzai. About this village all the much disturbed high-cliff-forming limestone ridges strike westward obliquely across the valley to the flanks of the Samána ridge.

From Ibrahimzai to Mirkhweli (the hill sanitarium for Kohát, having an elevation of 4,700 feet), 5 miles to the south-east, many alternations of the limestones, clays and sandstones are exposed, at first nearly vertical, then forming a wide synclinal basin, over the central, east and west, axis of which is the little station of Mirkhweli. All these beds are higher in the series than those of the succession given above, and have an estimated thickness of fully 4,000 feet.

The northern slopes and precipices of these hills are much concealed by a jungle, often densely luxuriant, of *Kao*, *Fullái*, *Mazzurra* (dwarf palm), *Sunhetta* and other bushes, sometimes attaining the growth of trees, and supporting vines. Hence the thicknesses of the zones in detail are not readily distinguishable, though they may be roughly stated at from two to four hundred feet. The following series was here made out (natural order):—

FIG. 1 (*see Map*).

14. Small limestone cap on summit of Mirkhweli.
13. Purple clay zone, under the Deputy Commissioner's house.
12. Thick capping of gray Alveolina limestone, forming the general hill top.
11. Red and purple earthy and sandstone rocks of the aspect of Murree beds.

Numerous fragments of a gray (green-weathering), coarse calcareous sandstone, conglomeratic with fragments of quartzite and white hornstone, are scattered over the slopes of Mirkhweli formed by this zone; its presence *in situ* here can scarcely be doubted.

10 Very thick zone of gray Alveolina limestone, defining the basin and forming the summit of Spirkhwet hill.
9. Red clays.
8. Very thick band of olive clays.
7. Dark ferruginous and greenish gray conglomerate, pebbles, white chert and quartzite.
6. Compact nummulitic and Alveolina limestone.
5. Red clay, overlying bands of dull sandstone.
4. Thick olive clays or shales.
3. Red clays.
2. Strong ridge of gray limestone.
1. Red clays and dull-coloured sandstones, a thick band, overlying limestones of similar kind as above-noted.

Beneath these last mentioned limestones are the uppermost beds of the succession previously given, so that this part of the Sabáthu group appears to have a thickness of 5,000 to 5,500 feet, roughly estimated.

From the summit of Mirkhweli, looking northwards, a fine view is obtained of the lofty limestone mountains, with the lower Samána ridge in front, forming a marked anticlinal curve, its southern side being sheeted with inclined curving beds of bare rock dotted with scattered jungle, while the ranges behind continue the northern slope of the curve. The alternation of gray limestone and thick softer zones is very visible, but nothing redder than the colour of the withered *Bubber* grass could be seen by the aid of a field glass. These mountains in Urakzai are so high, that even from this elevation (2,000 feet by aneroid above Ibrahimzai, and 4,700 feet above the sea), but little of the Sufed Koh, away towards its peak of Sikaram, could be seen.

In the opposite direction Mirkhweli dominates all the numerous limestone ridges and valleys occupied by the red rocks, &c., of the Kohát salt field.

From Ibrahimzai to Hangu the valley narrows and seems blocked by overlapping profiles of limestone ridges, one of these, north of the road, again showing distinctly a thick intercalated band of the red rocks between two limestone zones. At Hangu the latter is dark, containing but few fossils, and dips strongly to the north-east. Here a small valley running northwards reaches the Samána anticlinal beyond the frontier. By sending a messenger into this forbidden ground, I obtained specimens of dun lithographic textured limestone, some without fossils, but one full of *Alveolinæ* which was stated to have been taken from the southerly sloping beds of the ridge. Others were of white sandstone, rusty externally, the position of which was shown as a band along the foot of this Samána ridge. This white sandstone is identical with the blocks in the streams near Sherkot.

The hills south of the valley at this place are rugged, jungly, and grassy limestone masses, evidently continuing the undulation of the Mirkhweli section. At this part of the valley the soil has changed colour to darker brown and black tints, the cause of which is not very evident.

From Hangu to Togh, 34 miles from Kohát, the valley opens out considerably, the Samána ridge trending to the N. W., and long terrace-like mounds or fans are seen along its north side, similar to those observed in the Teri valley to the south (Mem. Geol. Sur., Vol. XI, p. 109). The frontage of the northern hills still shows the anticlinal slope of the Samána ridge, overtopped by the scarped edges of the beds in the mountains beyond. South and southwestward the same features continue as were noticed from Hangu; but a depression in the crest of the nearest range allows other parallel ridges with long horizontal outcrops of limestone to be seen beyond.

From Togh to Suruzai, 11 miles, the valley becomes still wider; its crest is passed at Kai, and the Zwymukht valley joining it from the north-west, the superficial waters unite to form the Shakkalli stream, which falls into the Kurram below Thal.

Most of the ground is covered with low accacia and Mazzurra jungle, and two lofty clusters of limestone mountains are seen to the westward, one the Dano hills over Tarawari and Darsamand, the other the Kadimuk group immediately north of Thal camp.

Near Togh, at the village of Bar, a mass of green clays with harder calcareous mudstone layers shows itself, dipping at 60° beneath the limestone of the southern side of the valley; it appears to be more than 200 feet thick, and has white *kallar* efflorescence, but no fossils could be found in it, its aspect is not unlike the *Sheor Kowra* clays of the Kohát salt field. This band seems to follow the course of the Shakkalli stream the whole way to and below Thal.

Near Kai there are long flat-topped, slightly hanging, terrace-like detrital hills, and on the "divide" between the Shakkalli and Kohát Towis there are some outcrops of dark green coarse gravelly and fine olive quartzose calcareous grits; these beds weather black, and the gravelly ones contain little fragments of limestone, mostly angular. Over these are green clays, similar to those at Bar, with purple bands and hard sandstone layers; the group is evidently much folded, on east and west lines. It is not improbable that the large valley here has been mainly excavated from these rocks, which possess more or less of a Subáthu aspect, but yielded no fossils except some broad striated plant impressions.

North of this the Samána ridge appears to inosculate with the higher limestone hills, the scarps of which, running west by north for the summit of Zawaghar (9,380 feet), still shew prominently two or more broad zones of shales, or other soft beds, between the harder ones of limestone, the dip having now come round to north-by-east.

To the west the Dano and Kadimuk mountains both show great anticlinal axes to the south, with strong northerly dips at 45°, and inner folds along the lesser elevations, uniting them with the Urakzai mountains northwards. To the south the rolling nummulitic limestone hills still shut in the valley extending nearly as far as Gandior, 54 miles from Kohát.

In the streams from the northward between Kai and Togh, I found numbers of light-coloured sandstone blocks, some of dark green quartzite, and many dark gray limestone pebbles, some of which contain shell fragments. Fragments of a dark gray limestone, weathering deeply to a brown colour, contain fragments

of *Rhynchonnella* with smaller bivalves, and a dark conglomeratic semi-oolitic calcareous grit, with white quartz in scattered grains, was found to enclose *Belemnites*. This stream comes from the highest part of the Samána ridge, where there is at least this evidence of the occurrence of the mesozoic rocks. The beds of streams further west towards Suruzai and Doaba are largely filled with gray shale detritus; one coming from Darsamand also contains dark sandstone fragments enclosing *Belemnites*, and the soil is frequently dark coloured or blackish recalling the cotton soil of the Deccàn.

From Suruzai to Gandior the character of the country is quite the same as just now described. Crossing the Mazzurra-covered plain from Gandior to the Darsamand mountain, near the base of the latter, greatly disturbed, dark rugged limestone with small nummulites and the little Rotalina characteristic of the eocene hill limestones are first seen. Some of the beds have a conglomeratic structure enclosing limestone lumps. A band of sandy limestone also appears, and then green quartzose grits, weathering to a black metallic colour. Beyond these is a strong rib of thick and thin-bedded compact gray limestone without fossils, dipping at high angles northwards and underlying a band of dark greenish and rusty olive or whitish hard coarse silicious sandstone, the dip of which is 50°. Similar sandstone and hard olive shaly beds occur on the further side of a hollow as if faulted against massive blue limestone, with a southerly dip at right angles. Sheets of this stretch up the mountain side forming the southern slopes of the anticlinal curve before mentioned. No fossils were found *in situ* in these limestones, but fragments from the hill contain *Rhynchonnella*, oysters and *Chemnitzia*-like spirals, and have a semi-oolitic structure.

Here all similarity to the nummulitic limestone has vanished, and a fault evidently separates the latter from the rocks of the hills. Moreover, these at the point struck must belong to a middle portion of the hill section, for the axis of the anticlinal bending downwards brings in higher beds to the eastward, likewise checked against the low outer rib of limestones, &c., having a northerly dip.

The fault here may be the great fractured junction feature of the eastern Upper Punjab section, but a hasty glance was all that could be obtained at the ground, the frontier lines here, as is often the case, being rather hypothetical. Between Gandior and Thal (63 miles from Kohát) this long valley, through which a main route from Afghanistan has lain since the time of Baber, becomes again narrow, though joined from the north by the Singroba glen. The mountain masses of Dano and Kadimuk shut out the more distant ones to the north in a great measure, and the southern side of the valley is no longer formed of limestone, but of almost horizontally bedded sandstone and clays, partly of the Murree group, and partly of Lower Siwalik aspect, the continuation of those occupying the Dallan valley. (Mem. Geol. Sur., Vol. XI, p. 101.)

At the southern bank of the river, not far from Gandior thannah, is a mass of limestone conglomerate with all the appearance of the usual valley beds, in a consoliated state, but it dips at 60° to the north-west, resting on or against greenish and purple clays, which come out from beneath the nummulitic limestones. The position of this conglomerate may perhaps be accounted for by supposing an old consolidated terrace to have been undercut by the river, and

to have subsided into this sloping attitude by its own weight. If not, the occurrence is remarkable.

The walled village and the camp at Thal are situated at the confluence of the Singroba stream with the river Kurram, and upon coarse detrital river accumulations of the local rocks. The elevation is supposed to be about, or somewhat over, 2,000 feet. Within a mile of the camp to the north, the high mountain of Kadimuk shows a short east and west anticlinal axis, around which the strong-bedded limestones form an elliptical quaquaversal dome.

Favoured by Colonel Gordon, commanding at Thal, with an extra guard, I was enabled to visit the lower part of this mountain. On the way there an exterior group of hills was crossed, composed of contorted, vertical and much disturbed, hard olive and gray quartzose sandstones, covered with a dark metallic lustrous film, and green, gray or purple clays, some of which are exceedingly fine and hard, with a splintry structure. Subordinate beds and bands of marly limestone also occur. Some of the latter contain well-preserved corals of two or three species, and in one bed of the externally dark-coloured sandstone I observed a few casts of small echinoderms.

Among the lowest beds of this exterior (? lower Sabáthu) group are unequally coarse sandstones, enclosing fragments and large blocks and blotches of limestone. Nearly in the same strike I also found a thick bed of limestone conglomerate, apparently reconstructed from such limestones as those of Kadimuk. The base is sandy, and lying on the rock, as if weathered out of this, a fragment of a *Belemnite* was picked up. Notwithstanding the interstratification, there is in consequence of the occurrence of this bed some appearance of a break low down in the group; but the relations of this to the rock of Kadimuk are those much more of faulted discordance than of unconformity. The whole outer group, in spite of the faulted appearance, sweeps round the axial western dip of the high mountain, and for some distance from the river strikes up the left bank of the Kurram.

At the southern base of the mountain a thin band of the dark-weathered sandstones, &c., separates a considerable mass of gray limestone from the Kadimuk anticlinal. This limestone has an uneven texture, showing small black specks like minute organisms, with a few narrow spines. Such limestone is not uncommon in the lower hill-nummulitics of the region north of Ráwalpindi plateau.

In the strong limestones of the mountain I found no fossils *in situ*, but fallen fragments contained anneloid tracks, oysters, bryozoa, or small corallines and corals, many small gastropoda, some like *Nerinæa*, and a few sections of impacted little bivalves, the aspect of the whole being that of older limestones than any of the eocene ones I am acquainted with.

One of the officers of the Kurram force (Mr. Macleod, 29th Punjab Infantry) informs me that some time ago near the summit of Kadimuk, beneath a limestone cliff, he found several ammonites lying on the surface of a softer band. I was unfortunately not able to procure any specimens of these, even through an inhabitant of Thal who knew where they are; for it appeared that part of the mountain was occupied by a wandering party of Ghilzais with whom the people of Thal were at feud.

Immediately across the Kurram, on the Afghan side opposite to Thal, is the very rugged hill of Bakkarkanch (flint-stone), entirely different in appearance from any of the neighbouring ones. It is chiefly formed of masses of hardened and altered brecciated beds, some being altered limestone or a silicious rock full of angular fragments of hornstone or flint,[1] usually mottled or banded with reddish or dark purple and gray tints. Others enclose also angular fragments of white earthy limestone, as if the whole had once formed flaggy beds; but the fragments now lie at all angles in the rock. Between these beds are purple, flaggy and gray or greenish shaly bands of Subáthu aspect, layers of a ferruginous red lateritic rock, and some of very hard thin-bedded limestone without fossils. The beds are broken into disconnected masses, and the cause of their alteration is not far to seek, for everywhere through the hill are numerous intrusions of hard, dark or decomposed, variously coarse, crystalline, syenitic and compact trap, weathering down so as to be less prominent than the silicious altered rocks. Looking from one of the summits towards the westward, a large space among lower hills was seen to be occupied by cores of the dark crystalline trap, the chief sources of which may be in this direction.

Besides the dark solid traps there are also what seem to be masses of agglomerate of trappean fragments, and fine-grained tufaceous traps, alternating in beds or layers. It was not found possible to recognise such an association of these lava-like rocks with the altered ones as would establish contemporaniety; but the entire assemblage has the mixed appearance one would expect to find near the core of a denuded volcanic vent.

Just beneath and in the under surface of one of the brecciated bands near the top of the ridge, old excavations were shown, made along the outcrop in order to extract a dark, gray and black heavy mineral which soils the fingers and marks paper. It occurs in but small quantity and seems to be a mixture of graphite with something else disseminated in the breccia; it is used by the natives as "kohl," and they call it of course súrma[2]. (I have not yet had time to examine it closely).

This is the first instance in which I have met with igneous rocks among any of the mesozoic or tertiary groups of the Punjab. The locality is fairly within the region of the Subáthu beds, and these trapps may be but an outlying portion of a larger igneous area to the westward towards Khost,[3] in which direction, as well as up the course of the Kurram as far as can be seen, the mountains present a softness of outline and a generally bare or withered-grass-covered aspect, entirely unlike that of the hills around on any other side.

Chaperoned by a couple of tame armed Waziris, in addition to the guard, I visited the scarped outcrop of their hills south of Thal. On the way thither, a low ridge between the Singroba and Shakkalli streams was found to consist

[1] Much used by the *Yagi* tribes for gun flints.

[2] This is perhaps the mineral mentioned as antimony occurring at Punjali-i-Shah Kurram river, by Agha Abbas, in Jour. As. Soc. Bengal. vol. XII, p. 595.

[3] I have seen specimens of asbestus from two miles west of Segai Kángah Khost, where it is so plentiful the people are said to make it into ropes; the locality is stated to be two long days' journey from Thal into Afghanistan.

of the same kind of hard, dark-weathered sandstones and olive and purple shales as occur between Thal and Kadimuk. The beds are vertical and folded, striking nearly N. N. E., and some of the sandstone bands contain badly preserved shells of large oysters, others those of a long and narrow but smaller form. South of the Shakkalli river is a mass of greenish gray clay coasting round the escarpment, extending down the Kurram, and very probably the same zone as is seen at intervals eastward as far as Togh. Resting upon this clay with a southerly dip, there is a band of some 100 or 150 feet of dark and lighter-coloured, mostly thin-bedded, compact, Alveolina limestone, immediately succeeded by a thin layer of calcareous concretionary pseudo-conglomerate, over which come the usual bright red clays and gray sandstones of the Murree group, the latter here sometimes enclosing small pebbles. Climbing to the top of the scarp, these and similar beds are seen to undulate over the country towards Dallan. Southwards they form large horizontally stratified elevations, amongst which a scarped hill at a distance, the scarp doubtles formed by a somewhat bent and twisted zone of nummulitic limestone, is the western termination of the Ragotungi ridge of the Kohát salt field, where that ridge passes into Waziri land. Still further off to the south is the rugged outline of a high ridge in the upper Siwalik sandstone and conglomerate basin north of Bannu.[1]

Near the edge of the scarp, not so much as 200 feet stratigraphically above the nummulitic *Alveolina* limestone, I found several fragments of large mammalian bones in a coarse pseudo-conglomeratic layer, but could find no teeth. One narrow bone, broken into three fragments, seemed to show the tubular structure of those belonging to birds. I have preserved the specimen, though a bad one.

This was all that I could ascertain of the local geology of Thal: the high mountains beyond the Kurram were too far off to form a close guess as to their composition. In the river and in the terrace above it, the travelled boulders and pebbles, loose or cemented into conglomerate, present a great variety of rocks, amongst which the only ones I could identify with those of the Indus deposits were a dark fine-grained syenitic gneiss and a well-known variety of white quartzite covered with conchoidal markings like gastropod sections, which occurs *in situ* among the Tanol rocks of Hazára. Others include varieties of gneiss, coarse and fine, micaceous schists, altered earthy and silicious rocks, red jasper, white and brown quartzite, purple quartzite, gray sandstone, gray and purple ferruginous limestone, dark hornblendic trap, white eurite, white semi-crystalline marble, red quartzite, many limestones, but none, that I observed, of slate. These may all be found hereafter on the flanks of the Sufed Koh.

Conclusion.—The route from Kushálgarh to Thal shows a considerable change in the upper nummulitic zone compared with its eastern sections as far as the river Jhelum. Near Murree this zone has an apparent thickness of some 6,000 feet, and is most largely composed of clays and sandstones frequently of red or reddish colours with subordinate bands of coarse fossiliferous (num-

[1] A nummulitic limestone patch in Waziri land, north of Bannu, shown on the sketch map, Records, Vol. X, p 107, has been a good deal misplaced to the westward of its real situation.

mulitic) sandstone, or of marly or pure limestone, and one prominent dark limestone band 700 feet thick.

In the Ráwalpindi plateau the zone is greatly disturbed, has apparently a less thickness, up to 1,500 or 2,000 feet, and comprises a few alternations of highly fossiliferous, marly and other nummulitic limestones, with red, purple and olive clays, &c.

Gypsum and petroleum occur along this part of the zone, chiefly in the lower ground, the former in considerable quantity; gypsum also is met with in red rocks of somewhat Subáthu aspect, their relations obscured by disturbance, among the Mochipuri mountains north of Murree, at Dungagali, &c.

In Bangásh on the road to Thal and southwards, these Subáthu eocene rocks occupy a large area, one part of their section alone giving an estimated thickness of more than an English mile, to which large additions should be made for the total bulk of the group, not less perhaps than 7,000 or 8,000 feet. The limestones here occur in thick zones of from one to over 300 feet, becoming more numerous northwards in the Mirkhweli region, and largely made up of beds containing *Alveolina* almost exclusively. Interstratified with these are thicker zones of rocks exactly resembling Murree beds, but including also many bands of olive clay. The gypsum of the group appears here in the salt field, and on its borders, but much more largely developed than to the east.

It would seem that the zone is changing again to the westward, the limestones disappearing in a great measure, and a mass of unusually hard sandstones with marine fossils and very thick greenish or gray and some purple clays forming a prominent part of the group in the neighbourhood of Thal.

A possible break at the top of the Salt-range nummulitic limestone has been suggested by Mr. Medlicott,[1] partly from the occurrence of a band of limestone conglomerate at the base of the overlying series. The presence of this detrital rock is not accompanied by any visible stratigraphic discordance, and in the section on the flank of Kadimuk north of Thal, we have a band of limestone conglomerate interstratified with the local lower part of the Subáthu beds. This occurrence is perhaps worth noting in connexion with the supposed break, with the abnormal northern junction of this Subáthu zone and the hill limestones, with the appearance of a transition across this break at Clifton (Murree), and with the absence of any unquestionable representative of the Subáthu zone north of the line of abnormal junction, so far as is yet known, nearer than the distant deposits on the Upper Indus, if even there.

Nothing has been found in this country antagonistic to views I have previously expressed regarding the nummulitic rocks of the Punjab (Records, Vol. X, p. 109, etc.), particularly as to the position of the Subáthu eocene beds above the mass of the eocene hill limestones[2]. Still some approach to the eocene hill limestone character among these rocks has been observed in scarcity of fossils and darkness of colour. Perhaps no feature is more prominent in the structural geology of the Punjab than the liability of its rocks to horizontal (lateral) varia-

[1] Memoirs, Vol. III, Pt. 2, p. 91, and Records, Vol IX, p. 57.

[2] See note 2, p. 130.

tion in thickness and character,—an observation quite borne out by this western part of the upper nummulitic group.

The occurrence of igneous, possibly volcanic, rocks in the Subáthu zone at Thal, should any of them prove contemporaneous, and should they be largely developed to the west, may introduce an entirely new feature, complicating the relations of this Subáthu group to the neighbouring tertiary or older rocks of that part of Afghanistan.

It may be possible that some of the Mirkhweli Subáthu limestones extend into the Urakzai mountains, the strike of parts of these lying in the same general direction as that of the Bangásh hills; but near Hangu, where the latter most nearly approach the former, a sudden difference of both dip and strike between the two sets of rocks was suggestive of a fault; nor were the interstratified red rocks of the Mirkhweli sections seen anywhere in the much-exposed Urakzai escarpments. Further west at Thal and Darsamand, where spurs from the northern mountains were reached, indications of fracture dividing the Subáthu zone from limestones of secondary age were found in both cases.

Of the age of the rocks forming these northern mountains, it has only been possible to collect some evidence of the presence of mesozoic rocks. The great height and bulk of the mountains, as well as the conspicuous northerly inclinations of their strata, together with their being so largely composed of limestones, leave ample room for the occurrence of all the eocene and mesozoic groups of the northern Punjab ranges, and space to spare for palæozoic ones besides; but in none of the streams coming from them, did I observe any fragments or fossils proving the existence of palæozoic rocks among these mountains.

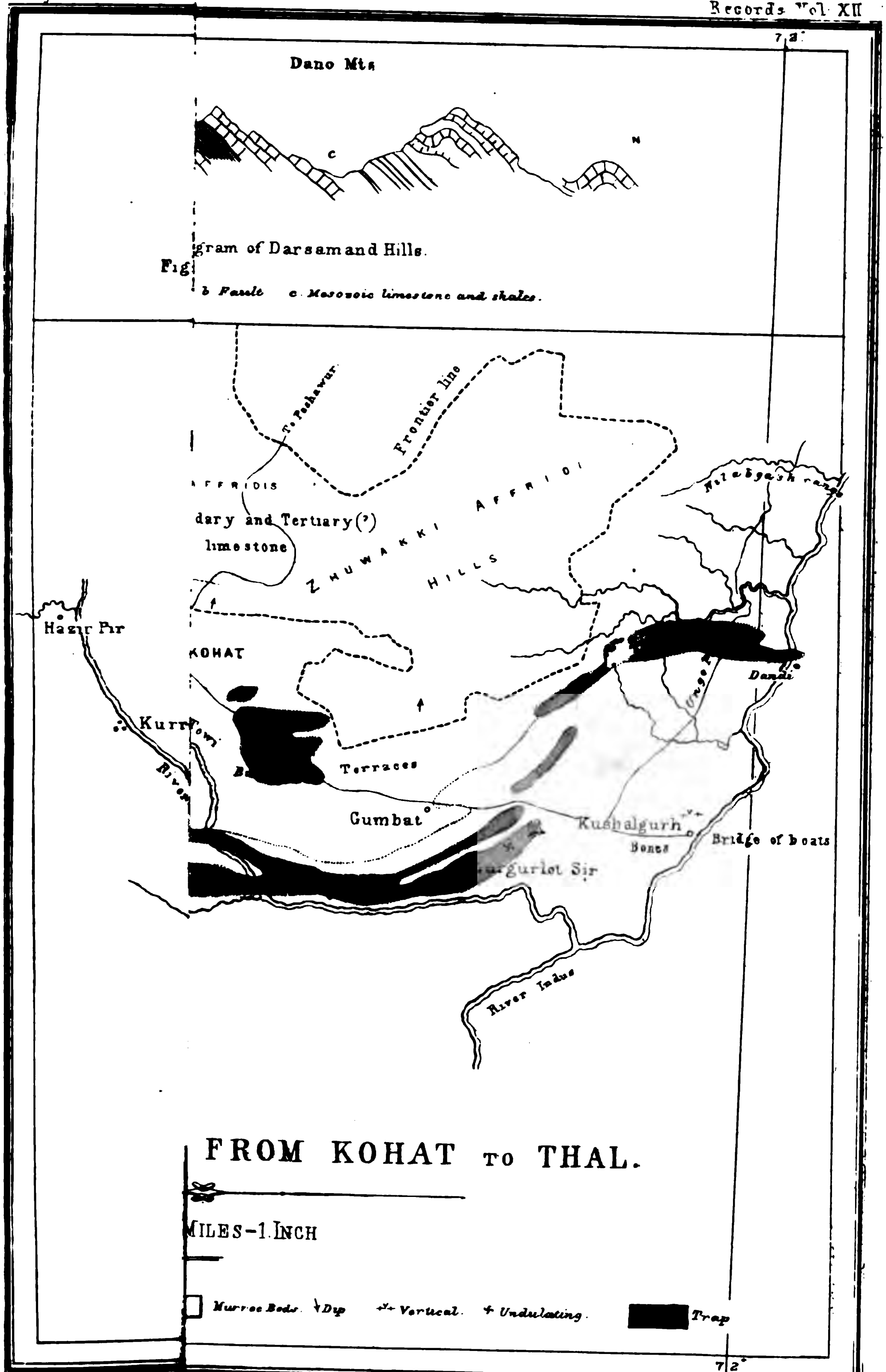
The very low horizon at which bones, presumably mammalian, were found south of Thal is not incompatible with the distribution of bone beds elsewhere in the Upper Punjab, these occurring even among the nummulitic rocks themselves. The circumstance may also be connected with the gradual disappearance in a southerly and westerly direction of nearly the whole of the great group of the lower tertiary mechanically formed beds, the absence of which is a marked feature in the westerly extension of the Salt Range, trans-Indus.

FURTHER NOTES ON THE GEOLOGY OF THE UPPER PUNJAB, *by* A. B. WYNNE, F.G.S., *Geological Survey of India.*

(Supplementary to those in Records, Geological Survey, vol. X.)

Description of the ground.—The rugged district of Hazára stretches far into the regions of the Western Himalaya between the rivers Indus and Kishenganga, and embraces the native hill states of Amb and Kaghán as well as the portion directly under British rule. Its mountains, being parts of the greater ranges, present a somewhat complex assemblage of lofty spurs, rather than distinctly individual chains.

The long glen of Kaghán curves to the eastward-by-north between great snowy ridges. Its stream is the Nainsúk, or Kunhar, river, which enters the



On Stone by S. Khad

Jhelum below Muzaffarabad. Between the north-western watershed of the Kaghán valley and another great mountain spur from the northwards, the upper waters of the local river Sirun find their way southwards towards the Indus through the valley of Bogurmang. On the east of this valley is the lofty truncated peak called Músa-ka Masala (the praying carpet of Moses), 13,378', situated in the border country of the hill-men nominally within our frontier; and on the west are high elevations called Palleja Behisht (Heaven) and Shaitán-ka-gali (the devil's neck or pass). Further west the Black mountains (scene of late frontier warfare) rise, on this side of the unknown, or at least unmapped, portion of the upper Indus channel.

One march westward of the lower Nainsúk, at a much greater elevation surrounded by still higher mountains, is the flat lake-like plain on the course of the river Sirun forming the detritus-filled valley of Pakli.

Between the Pakli valley and the Indus rises the mass of mountains in the state of Amb, culminating at Bahingra in a height of 8,608 feet above sea level.

A broad cluster of hills having elevations of four, five, and six thousand feet spreads from the Sirun to the valley of the Dore; and from near the junction of these two streams the most isolated ridge in the whole country, that of Gandgarh, trends in a south-westerly direction, rising to an elevation of 4,137 feet between the Hazára plain and the river Indus.

Again, occupying the southern side of the district is another, broader, lofty tract, presenting endless alternations of confluent ridge and valley, with a marked north-east south-west strike. This elevated tract rises from the Nainsúk torrent, near Ghari Habibula, and with altitudes of 8,000 and 9,000 feet overlooks that river and the Jhelum; then, passing between the stations of Murree and Abbottabad, it gradually becomes less elevated, though still presenting high summits and long south-westerly valleys, till it leaves the district as a part of the Márgalla range, near the grand trunk road from Ráwalpindi to Hasan Abdál.

The Indus valley is a deep defile amongst the mountains, where, coming from the north, the river first bounds this district, then passing Derband, Amb, and Sittána, its valley expands to a width of about two miles at Torbela, a few miles below which place it opens out upon the plains of Chuch and Yusufzai.

All over southern Hazára the more or less north-east south-west run of the valleys, streams, and ridges coincides generally with the strike of the rocks. In central Hazára, disturbance of the strike would appear to have produced a less regular structure of the ground as to depressions. In the Gandgarh range, this ridge is itself a strike-feature, and the mountain torrents cross the bedding of the rocks; while in northern Hazára, in Agror, Bogurmang and the lower part of the Kaghán valley, the northerly and north-westerly run of the rocks, resulting in many marked features of the ground, approximates more to the general Himalayan bearing eastward of the river Jhelum, than to the abruptly deflected south-westerly strike of the rocks westward of the same river.

Geological structure.—I have already given some account of the outer Himalayan series in Hazára (Rec. Geol. Surv. Ind., vol. X, part 3); but now that it is to be noticed at more length, it will be well to subjoin a short

tabular list of these Hazára groups, placed as far as possible in their natural order of stratigraphical succession as follows:—

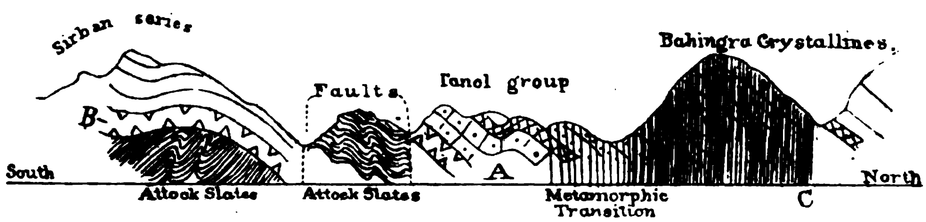
	PLEISTOCENE	12	Northern detrital drift.	
		11	Alluvium and river drift.	
		10	Post-tertiary valley or lake deposits.	
CAINO-ZOIC.	?	9	Murree beds, sandstones and clays transitional with	
	EOCENE	8	Upper nummulitic beds, limestones, sandstones, clays.	
		7	Hill nummulitic limestone older than above.	
MESO-ZOIC.	CRETACEOUS	6	Limestones chiefly.	
	JURASSIC ...	5	Ditto, black shale (Spiti) and dark sandstones.	
	TRIASSIC ...	4	Limestones, dolomites, breccias, shales, &c.	
PROBABLY PALÆOZOIC.	?	3	Infra-triassic sandstones, breccias, &c.	? same.
	?	2	Tanol series—Quartzites, sandstones, dolomites, &c.	
	(*Observe: 2 and 3*		*may possibly or probably be parts of one group.*)	
	?	1	Attock slate series: Fine slates and grits, with limestone bands, sometimes largely developed.	
		B	Intrusive traps, in Attock slates and Tanols also in metamorphic rocks.	
	?	A	Hazára gneiss and the most crystalline altered beds.	

A. Highly crystalline metamorphic and azoic rocks.—It will be observed that I have given these rocks a separate place at foot of the list, an arrangement which might be supposed to convey the idea that they were really the oldest part of the series; and under ordinary circumstances it would appear easy to consider the granitoid gneiss as the fundamental portion of the whole. The observations made in the field have, however, shown indications of the presence of the singular Himalayan phenomenon of highly metamorphic rocks resting upon others possessing far less, or even in cases little or no, traces of having undergone metamorphism. Hence it is necessary to avoid hasty conclusions; for, if the stratigraphical superposition to be described really represents the normal sequence, the inference follows that among these metamorphic rocks a portion at least may be representative of palæozoic or even newer groups.

The unaltered rocks lie in the southern part of the district, the most altered in the northern region; but in passing from the former to the latter, neither a continuous, nor a simply interrupted or inverted, descending section is found. From the tertiary beds down to the slates, No. 1 (omitting No. 2 as doubtfully present), a descending series may be observed, with two breaks, the lowest of which is prominently marked. From these slates towards the Hazára gneiss, an ascending series, differing from that just mentioned, prevails; and in the gneiss region itself there are traces of interstratification apparent, the position and inclination of the bands being suggestive of these altered rocks occupying a high place in the northern series. The sequence could be accounted for if this northern series could be proved, by any unconformable contact, older and entirely different from the southern one; but at the point where operations had to be discontinued, it appeared to be gradually becoming evident that the great Tanol group of the northern series was passing laterally into the infra-triassic group of the southern and Sirban mountain sections (see Mem. Geol. Surv., vol. IX, part 3: Description of the Geology of Sirban). This would assert its position to be newer or higher than the Attock slates; while its upper

beds pass by prevalence of metamorphism into the transformed, crystalline, northern rocks with a strong appearance of underlying a most intensely altered portion of these.

The observation may in a general way be made, that the metamorphism of the rocks of the northern part of the district exhibits a lateral or geographical rather than any development coinciding with antiquity of the strata. Inversion, apparent or obscure, is often made to explain the difficulty of such a case, but the employment of this supposition may have a limit; as in the present instance, where, if the Tanol and infra-trias groups should prove identical, or even in parallel superposition, physical impossibility would be involved.



A glance at the accompanying diagram will explain this: the lower portion of the Tanol group (A) is very similar to the general aspect of the infra-triassic group (B), and as I have observed, they seem to unite in the Tandiáni mountains, eastward of Abbottabad. But the infra-triassic group (B) rests unconformably upon the Attock slates, and its basal bed is a conglomerate largely made up of fragments of this slate series. Consequently the presumption is that the Tanol group is newer than the Attock slates, and not part of an inverted series, the oldest portion of which would be represented by the metamorphic rocks.

It is unfortunate that, however closely the groups A and B in the above diagram may be united, the succession upon the northern side of the crystalline area (C) is unlikely to become known, owing to inaccessibility of the country; otherwise, its comparison with the southern extra-metamorphic series would be in all probability instructive.

In the Pír Panjál region, not very remote from Hazára, an opportunity has occurred of studying the relations of both sides of a chain, the core of which is also formed of gneiss similar to, if not identical with, that of Hazára; and Mr. Lydekker, to whose research we are indebted for the information, is of opinion that a clear case of inversion is there established, and the series on each side of the crystalline axis is the same (Rec. Geol. Surv. Ind., vol. XI, p. 30). Comparing that region with this, we should find little possibility of identifying the flanking series, although this Pír Panjál chain, between Kashmir and the Punjáb, presents an assemblage of rocks continuous with those of the Kájnág range, north of the Vedusta, or upper Jhelum, and doubtless continuous in a general way with the series of upper Hazára, perhaps, however, beyond the limits occupied by the Tanol and immediately associated type of rocks.

The Pír Panjál chain, with its gneiss and slates, &c., is considered as belonging to the Central Himalayan System (Annl. Rept. Rec. Geol. Surv.

Ind., 1878); its gneiss is recognised as re-appearing in the Kájnág range (Lydekker, *l. c.*), and I can answer for the lithological identity between that of Hazára and the transported masses of the Kájnág gneiss scattered along the Vedusta valley on the Murree route into Kashmir. Still I am quite unable to identify the other members of the Hazára series, generally or in detail, with those rocks which Mr. Lydekker has found displayed along the Pír Panjál range. To show the contrast, I propose, after describing the local series here, to place it and that of the country to the east (as recorded) in parallel columns.

The Hazára gneiss—is a completely crystalline granitoid rock, of whitish gray colour, composed of quartz, felspar, and black mica (biotite), white mica (muscovite) being often present as an accessory; and the rock is rendered porphyritic by an abundance of large twin crystals of pinkish or flesh-coloured orthoclase measuring from two to eight inches in height, more commonly from three to four inches being the longest dimensions. These lie in all directions in the matrix, sometimes affecting a linear arrangement, which may mark the former lines of now obliterated stratification. Schorl is locally present, and garnets are occasionally seen, both as rather unfrequent accessories. Separate bands or veins of rock crystal or opaque quartz are rare, but dykes of easily decomposing trap, apparently greenstone, are not unusual.

I have often sought near the junction of the crystalline rock with the adjacent schists for evidence as to its being intrusive or otherwise; and in some directions I have found what appeared to be distinct dykes or veins among the schistose rocks; but contrasting with these, and sometimes in contiguous localities, the schists exhibited a gradual transition towards the main granitoid mass by reason of great intensity of metamorphism, the region of actual contact being, however, defined within rather narrow limits.

For instance, on the southern ascent of the Susul Gali pass into Agror, I found masses of the adjoining schists included in the crystalline gneiss, presenting many gradations of alteration; and although the stratification was still discernable, parts were as crystalline as the adjacent gneiss, enclosing the same large felspar crystals, and other parts had assumed the form of a gneiss of much finer grain than that of the main mass.

In other cases, as near Mánsahra, detached masses of the schistose rocks were found entangled and enveloped amidst the gneiss without exhibiting this extreme amount of alteration, not being indeed more altered than the rest of the adjacent schistose beds. The country generally is one in which a wide or distant view often shows more of the broad structural relations than is gathered from close inspection of details; whilst in places, nothing is open to immediate view except small features, the continuity of which cannot be observed or relied upon, yet the facts concerning which must take their own place in forming conclusions. Thus, with regard to the gneiss, few traces of stratification are to be found in minute detail, though the outline of one of its principal masses, the Bahingra mountain, presents the normal Himalayan feature (common among the stratified groups) of a steep outcrop slope towards the plains, and a long gentle declivity towards the mountains of the interior. Coinciding with this form, and lying as if in alternately bedded masses, are groups of well stratified quartzites and schists,

sometimes cropping out along the whole of one side of a spur the opposite slope of which presents a sheet of the gneiss for many miles.

The whole aspect of the gneissic or granitoid region, so far as visited, gives the impression that an extensive series of mechanically formed detrital rocks has undergone transformation, the metamorphism being locally intense, and its extreme results expressed by a very abrupt transition from highly altered schists into gneiss itself.

Less highly altered azoic rocks.—The schists and quartzites adjacent to the gneissic area are, as a general rule, distinctly stratified; and, no matter in what direction inclined, they almost invariably dip towards exposures of the gneiss. They present the somewhat peculiar feature that they occupy, so far as yet traced, the deepest valleys, such as those of the Nainsúk, Sirun, and Indus; this feature, together with their dip, intensifying the appearance which they present of underlying the gneiss.

The metamorphism of these rocks bears a more or less constant relation of place to the margin of the gneissic tract, though it possesses no definite outer boundary. It appears on the left (Hazára) bank of the Indus to travel across the stratification of beds that are less altered further away upon the same strike, as though it were an effect related to the presence of the gneiss among the Buneyr hills in the wild tract beyond that river; or it might be perhaps inferred that the altered rocks here, lying lower than some in the neighbouring country, indicates the presence of plutonic ones at a depth beneath this region no greater than the distance within which the rocks at the surface nearest to the gneiss have been most metamorphosed.

The altered rocks in this situation consist chiefly of various talcose or micaceous schists, sometimes slaty, sometimes even conglomeratic from the presence of white quartz or quartzite pebbles; they are rarely calcareous, but sometimes contain bands of compact and rusty-looking dolomite or magnesian limestone.

B. Intrusive traps.—In both the more and the less crystalline metamorphic groups (as well as in the Tanol series), igneous rocks are not uncommonly met with as dykes or intrusions. One of these near the border of the Amb country, south of the Bahingra mountains, is of considerable size. Generally speaking, these rocks are of a dark, dense, variously crystalline greenstone, seldom porphyritic and never amygdaloidal. They do not present recognisable signs of having partaken of the metamorphism of the associated beds, but they are frequently weathered to an extreme degree, this condition perhaps having some connexion with their position.

1.—*Attock slates: (Azoic).*—The general appearance of this group has been already more than once described. It consists of various dark, olive, black or brownish fine earthy slates, sometimes with purple bands and occasionally interstratified with greenish fine-grained sandstones. Bands of compact, waved, pale and dark gray or rusty-brownish limestone are locally numerous; though comparatively rare in some localities, in others, as in the Gandgarh range, they assume an enormous development.

Here too these limestones include among their upper layers a band or bands of compact white or greenish semi-translucent waxy-looking thin-bedded marble,

2. *Tanol group: (Azoic).*—Lying between the Attock slate region and the metamorphic area is a great group of rocks, the existence of which was unknown until the past season, and the analogues of which I am unable to discover among the recorded sections of Kashmir and the Pír Panjál. I have called these rocks for sake of distinction the "Tanôl" group, from the ancient name of the country they occupy.

These beds are always associated with the schists of the northern series, and they appear to pass both into and underneath a considerable section of these schistose rocks. They comprise an enormous thickness of gray or drab quartzose or quartzite rocks, in rapid alternation with dark earthy bands, flaggy, shaly or slightly schistose. Many of the dark intervening bands remote from the gneiss are in appearance scarcely altered, and have much the look of Indian jurassic plant beds. Others of the alternating layers are exceedingly fine, unctuous, slaty argillite, sometimes associated with conglomeratic slates, the pebbles of which, ranging up to the size of goose eggs, are usually formed of white quartz or quartzite.

The quarzites or quartz rocks frequently show lines of oblique lamination, or other lines of deposition; and they include amongst them beds of almost unchanged sandstone, the weathered surfaces of which have the small warty protuberances such as are frequently observed upon certain mesozoic sandstones in the peninsular Indian area.

Some of these Tanol rocks, towards the apparently upper part of the group, are of a clear grayish white color, soft enough to mark the fingers when handled, and with these the slaty rocks of paler color prevail. The soft white rock is not calcareous, nor has it a strongly argillaceous appearance; reduced to fine powder it is but slightly soluble in acids, even when boiled for a considerable time: it fuses on thin edges to a white glass, and in powder on charcoal to a somewhat coherent semi-fused mass, giving no alumina reaction with nitrate of cobalt, nor any distinct magnesia color. This powder fuses with effervescence in carbonate of soda, but is not quite fusible in borax. The color of the bead given with reagents was not definite enough to form an opinion by. The specific gravity of the pieces examined was about 2·78. These soft white beds, though retaining a good deal of their detrital aspect, have undergone so much metamorphism that it is uncertain what kind of sandstones they originally were; and yet the strata amongst which they are intercalated do not seem to have suffered extreme alteration.

Occupying synclinal folds, or else occurring at various horizons, in the Tanol group are thick zones of variously colored pseudo-brecciated, silicious, cherty or compact gray, black, and buff dolomitic limestone, with which are occasionally associated intensely black graphitic and sulphurous shales, or else purple and red sandstones and slaty bands.

The Tanol group extends from near Mangli (and probably further east among the Tandiáni mountains) by Sherwán towards the Indus, passing north of the Gandgarh range. Its relations to the Attock slates on which it seems to rest are obscure, the junction being frequently either a line of dislocation or concealed by quartzose debris; but still the disposition of the two groups in the neighbourhood of the lower Sirun and Dore rivers is one consistent with unconformity.

Trap rocks, chiefly intrusive and perhaps intrusively interbedded, are found in the group, mostly among the more metamorphosed portions, and of similar dense crystalline basic kinds to those of the altered rocks.

I have not been able to detect any organic remains among these Tanol rocks.

The apparent superposition and probable unconformity of the Tanol upon the Attock slate group, and the presence of silicious dolomites and red sandstones in the lower part of the former, as well as in the lower part of the infra-Trias of Sirban mountain, are points of resemblance which would indicate a connexion between these infra-triassic beds and the Tanols; but the latter exhibit a thickness enormously greater than that of the group overlying the slates in Sirban, nor has the distinct evidence of conglomerate formed of slate debris been found at the base of the Tanol group, neither have any fossiliferous limestones or other beds identifiable with the Sirban Trias been met with. Notwithstanding this, on tracing the Tanol group and the Sirban beds to the north-east, they seem to unite in one great series in the lofty mountains near Tandiání, sweeping over an anticlinal axis near the camping stage of Mangli or Manghal. The decision of this important point must be reserved until the Tandiání hills can be examined.

The thickness of the Tanol group exposed in the sections from the Miánkháki stream northwards can scarcely be less than 20,000 feet, up to the place where they pass into the metamorphic rocks. Possibly some part of this thickness may be repeated; in so disturbed a region it is difficult to say repetition does not occur, but general appearances are against it. Nor is it easy to account for the absence of the mesozoic series of the southern hills unless they may possibly be partly represented by some of the dolomitic zones, or else metamorphosed beyond recognition. (See Section No. 4).

Far away to the north, in the Palleja heights, overhanging Bogurmang, I could see among the snows a basin-like arrangement of strongly bedded rocks as though resting unconformably upon the metamorphics. Of these the only specimen I could obtain was one of a dark dense limestone. Should limestones prevail, and the sharply scarped form of the cliffs looked as if this were likely, the mesozoic series may in part be represented there, or perhaps some of the Kashmir carboniferous or other groups.

The Southern Hazára Series.—Of the rocks in this part of the district more was already known than of those to the north. The limestones of the hilly tract between the Attock slates and the Ráwalpindí upland or the Murree hills, present an extremely confused, contorted and faulted assemblage of mesozoic and eocene strata, an epitome of which is afforded by the instructive sections of Sirban mountain described in the memoir already quoted. The main features of the whole tract are, a large development of the triassic and of the great hill-nummulitic limestones, the disappearance westward of the jurassic (Spiti) shales, and their place being taken by limestones containing *Trigoniæ*, amongst which *T. ventricosa* is a prominent form, together with some poor and fragmentary *Ammonites*, *Belemnites*, *Gryphæa*, and small brachiopods; also the disappearance of the infra-Trias group of Sirban, which is at least no longer recognisable to

the westward, nor has the cretaceous band there observed been found reappearing with the same character, if at all elsewhere in this district.

For fuller detail I refer the reader to the already described Sirban sections (Mem. Geol. Surv. Ind., vol. IX, Art 3, p. 331); but to convey a general idea here, I abstract the table of succession given in that paper at p. 2, *viz.*—

6. NUMMULITIC.—Thick limestones with some shales, fossils in places.
5. CRETACEOUS.—Thin-bedded limestones without fossils apparently.
   Impure ferruginous sandy limestone, weathering rusty—fossils.
4. JURASSIC.—Black Spiti shales.

Unconformity.

3. TRIASSIC.—Thin-bedded limestone and slaty shales, dolomite, limestone; fossiliferous (*Megalodon* and other) beds.
2. BELOW THE TRIAS.—[Infra-Trias] Hæmatite, dolomite, quartzite, sandstones and breccia.

Marked Unconformity.

1. PALÆOZOIC ?.—Attock slate.

Of these groups the Attock slates, ascertained from larger developments to be the same group exposed at Attock, have been already described.

The infra-Trias, however, requires a few words of description in order to enable a comparison to be formed between it and the Tanol group. It seemed to show a triple sub-division, the lower one consisting chiefly of red sandstones, red shales, and red quartzitic dolomites, underlying another zone of dolomites of lighter color often highly silicious and of very considerable thickness. These words would apply almost equally to those well marked red and lighter colored dolomitic zones of the lower, but not lowest, part of the Tanol group. The sections given in the Sirban memoir may be compared with that crossing the Tanol group, No. 4, appended to this paper.

The third sub-division, composed of hæmatitic rocks, quartz breccias, sandstones and shales, seems less capable of recognition to the north; but it might be there subordinate either from lateral change or blending with the dolomitic zones.

4. *Triassic.*—In this group the further examination of Hazára has revealed the existence of a great development of limestones with some shales. Many of the former show features characteristic of the Sirban exposure, yet are most frequently without the arrangement into more or less defined, though sometimes obscurely, fossiliferous zones. Owing to this local character the exact lines of the Sirban section have not been traceable amid the larger and thicker exposures elsewhere. Although the most characteristic feature,—the presence of numbers of impacted *Dicerocardia*, sometimes accompanied by shells of the *Megalodon*, visible in section only,—has been observed in one or two localities; the point of itself is insufficient to establish actual identity of these fossiliferous beds, but decisive as to the general age. Outlines of these fossils from the Sirban rocks are figured at page 8 (338) of the Sirban paper, *l. c.*

Other fossils among the triassic beds generally are so few, so fragmentary, and so rarely met with, that it is often doubtful whether the beds are really

triassic or jurassic, nothing being left for guidance but the not very definite point of lithological character.

The thickness of these rocks in the neighbourhood of Khánpur, however difficult to fix on account of plications, can scarcely be estimated at less than 3,000 or 4,000 feet, perhaps more than double the amount of the triassic series of Sirban, where the best exposed sections show the formation sheeting the northern side of the mountain, with inclinations of less than 35°, over a slope a mile and a half long with a rise of 2,000 feet. This being taken as the basis of calculation affords the inference that the Sirban trias formation may have a total thickness of between 1,500 and 2,000 feet.

The distribution of the formation as far as traced is shown upon the sketch map annexed; it seems to have suffered extensive inversion near Bagnotar on the Murree and Abbottabad road.

5. *Jurassic.*—The jurassic rocks of the southern region of Hazára are very subordinate, as to extent or thickness, to the underlying group. They are, however, traceable by numerous complicated exposures among the disturbances so prevalent in these hills. They appear amongst masses of nummulitic beds, at Shah Kabul summit, in the Khánpur country, as a rusty group of earthy limestone, shales of dark and light color, and occasional sandstone bands, identified by Dr. Stoliczka as similar to his Gieumal sandstone of other Hímalayan regions. Similar rocks reappear near Garm Thun; and they are met again, though scarcely ever with exactly the same character, edging the southern frontage of the Márgalla range, and in the interior of the mass of hills crossed by the old bridle track from Murree, *viâ* Mári, to Abbottabad.

In the higher hills the jurassic formation includes in places a well-developed zone or zones of black Spiti shale, containing fossils characteristic of that group in Spiti, but both these shales and their fossils appear to be entirely wanting to the west, where a band almost made up of ill-preserved *Trigonia ventricosa* (not found in the higher hills) appears towards Shaladitta, associated with layers containing *Ammonites, Gryphœa, aud Belemnites*. But it is not clear whether these fossiliferous beds to the west are newer or older than the Spiti shales,[1] the groups never having been found in contact or in the same section; and the relation in both cases to the succeeding eocene rocks, so far as can be made out, being that of conformity.

The whole formation seldom exceeds a few hundred feet at most; but where its lowest limits may be, among limestone masses, part of which are at least triassic, though the upper portion may be newer, it is impossible to say without better palæontological evidence than is available, and without the reappearance of the Sirban discordance.

6. *Cretaceous.*—The few beds referred by Dr. Waagen from their fossils to this formation at Sirban are the only established case of its occurrence among these hills. In many places, however, there intervenes between the known

[1] These western fossiliferous jurassic rocks are stated in the lately published Manual of the Geology of India, p. 503, to "appear to be a continuation of the Gieumal sandstone." So far as I am aware, there are no sufficient grounds for the assertion as yet discovered.

jurassic and the nummulite-bearing limestones, a mass of light or dark-colored limestones without fossils, which perhaps belongs to the cretaceous period. . . .

The fragmentary *Ammonites* found in a limestone rib southward of Huveliyan (see *ante* p. 121) on the opposite side of the Dore valley from the cretaceous band of Sirban, occurred in limestones with somewhat the aspect of those of the cretaceous zone; but it is not even known whether the specimens can be determined.

7. *Nummulitic.*—The nummulitic eocene limestones of these hills presents no peculiarity beyond the general features described in former papers (Rec. Geol. Surv. Ind., vol. VI, pt. 3, vol. VII, pt. 2, vol. X, pt. 3; Q. Jnl. Geol. Soc., London, vol. XXX, p. 61, vol. XXXIV, p. 347).

It occurs very extensively, yet its thickness, which must be very great, is difficult to determine on account of the frequent faults and the disturbance of the beds. One section from Murree northwards would indicate a greater thickness than 2,700 feet for what is but a part of the series; and from 3,000 to 5,000 feet may be a probable, though necessarily a very conjectural, estimate for the whole.

These dark gray eocene limestones of the outer Himalayan region, alternating frequently in some places with olive shales which are almost entirely absent in others, and containing sometimes an abundance of small Foraminifera, sometimes scarcely a fossil distinguishable with a lens, are in a manner peculiar to the northern regions of the Punjab, as has been already pointed out (*l. c.*, above). There seems to be a possibility that in the higher portion of the hills, traversed by the upper Abbottabad and Murree road, the group includes in its lower part dark red and blackish gypseous shales and sandstones of the aspect of those found in the base of the succeeding tertiary sandstone series, but the point is obscure. There is also a considerable appearance of transition from the upper or outermost beds of the Hazára hill-nummulitic rocks into the upper nummulitic zone near Murree, which is transitional with the lower tertiary sandstones and clays just mentioned. The apparent passage is deducible from the arrangement of the rocks in the region of the abnormal contact between the Hill limestones and outer tertiary zone, and therefore less trustworthy than it might be; still such appearances, even in disturbed localities, should not be overlooked (see Section No. 5 annexed).

The upper nummulitic beds of this district, scarcely appear within the hilly tract from Mochpura mountains westward in other than doubtful exposures. Some of its beds are faulted into junction with the hill-nummulitic and jurassic rocks between Shaladitta and Garm Thun, on the road from Ráwalpindi to Khánpur; and the faulted mass of red rocks with gypsum, in the Haro Kas below Dungagali (north of Murree), may either belong to this group or be intercalated, as just now mentioned, at a much lower position with the eocene limestones.

Another more extensive exposure of red argillaceous and arenaceous rocks was met with this season capping the Lachikhun mountain, in the range overlooking the Nainsúk at Ghari Habibula from the east. Lithologically these might represent a variety of the lower tertiary sandstones (Murree beds), but

have a harder, more slaty and more prominently red aspect. They are intersected by numerous parallel veins of white carbonate of lime, which is one of the characteristic appearances of the Murree beds near their disturbed junction with the hill rocks. There are, however, no such masses of nummulitic and mesozoic limestones associated with these beds as occur further to the south-west. Dolomites, limestones, and black carbonaceous or graphitic shales appear immediately beneath them; but these beds have much more the aspect of the infra-trias or Tanol rocks than of the newer limestones, &c., and none of them contain fossils so far as could be discovered. On one spur of the mountain near Kulis village, a situation which would indicate an inferior position to the red beds, I observed numerous shaken angular blocks of limestone containing *Nummulites*. These, although they could not be pronounced *in situ*, did not appear to have been far removed from their original place, and they would indicate an extension in this direction of the Hazára eocene formation.

The whole of the red series and associated beds on this range appear to rest unconformably upon the metamorphic schists, of which the lower half of the mountain mass is entirely composed; but no clean sections could be observed, and snow concealed much of the higher ground.

A small vein of galena among the schists in the Kakal ravine, not far from Kulis, is only worth mentioning to state that the quantity is so very small as to be economically worthless, so far as this one vein is concerned, and unless others of much larger proportions are concealed in the vicinity. On examination at Calcutta specimens of the ore were found to be argentiferous, as is very commonly the case.

Before noticing the more superficial and less important deposits, it may be useful to glance at the comparative aspect of the two great series of rocks—those of the Himalayan system in Kashmír and those of the Hazára region, still further west. In order to present the state of the case as definitely as possible, I have taken the Kashmir series from Mr. Lydekker's papers, and placed it side by side with that of Hazára in a tabular form (annexed).

Commencing with the older rocks, it will be observed from what I have already stated, that the first discrepancy to be met with is in the position of the gneiss of the two regions. Mr. Lydekker refers to two kinds of Himalayan gneiss, but considers that occupying all or most of the gneiss areas on his map as of one kind, except perhaps the central portion of the Zánskár range, (not marked on his map, (Records, Vol. XI, p. 30) but forming the north-west south-east watershed north-east of and above Darwas). This great expanse of identical gneiss, presenting the same relation of conformity and transition into the overlying silurian schists, is of course newer than the "central gneiss" of pre-silurian age. The Kájnág ridge belongs to the Pír Panjál range, and its gneiss is at least lithologically identical with that of Hazára. But, though in the Pír Panjál this gneiss forms so well marked a base to the stratigraphic system of a widely-extended area, and the apparent alternation of the gneiss with quartzites and schists in Hazára affords a further point of similarity, its general situation with regard to the rest of the Hazára series conveys no appearance of its being a fundamental rock or the basal member of the stratified series.

Comparative Table of the Kashmir and Hazara Series on different sides of the Jhelum Valley synclinial or deflection of the Himalayan strike.

(So far as at present known).

	Hazara Series.		Kashmir Series.		
Cainozoic ...	Pleistocene ...	Northern detrital drift ... Alluvium and river deposits ... Post tertiary valley or lake deposits.		Alluvium. Karewahs ...	Probably equivalent to the post tertiary of Hazara.
			Siwalik ...	Upper. Lower—Nahan.	
	?	Murree beds.	Sirmur ...	Kasauli, Dagshai	These groups may be equivalent to the Murree beds.
	Eocene ...	Upper Nummulitic beds ...		Sabathu ...	These beds are identical in both regions.
		Hill Nummulitic limestones ...		....	3,000 to 5,000 feet of limestones absent in Kashmir.
Mesozoic ...	Cretaceous ...	Cretaceous limestones ...		....	Unknown in Kashmir as yet.
	Jurassic ...	Jurassic limestones, &c. ...		....	Unrecorded as yet in Kashmir.
		(Unconformity at Sir Ban).			
	Triassic ...	Triassic limestones, &c. { Upper	Trias ...	Upper ...	The upper beds may be those of Sir Ban in Hazára.
		Lower		Lower ...	From description in both regions not unlike.
Palæozoic ...	?	Infra-triassic sandstones, breccias, &c., and Tanol series, Quartzites, &c., metamorphosed northwards, and passing into gneiss and crystalline rocks.	Carboniferous	Including Kiol Krol and great limestone.	The Kiol series only seems to present any similarity to the Tanol group.
		Unconformity.			
	?	Attock slates, partly altered ...	Silurian ...	Pangi slates, Panjal rocks	The Attock slates contain limestones the silurian of Kashmir does not, but the Pangi slates to S. E. do.
		Intrusive traps.			
	The Hazára gneiss is identical with some of that in Kashmir, but differently placed.		Gneiss ...	Gneiss ...	The gneiss is difficult to recognise as the same in both regions, though partly lithologically identical.

The two unconformities in the Hazára series are unrecorded in Kashmir or Jamú.

Mr. Lydekker has specially pointed out the conformity of this Himalayan gneiss to the overlying silurian strata, but in Hazára, whether the contact rocks may be correlated with his Pír Panjál and Pángi groups or not, the manner of their junction as described above (see section No. 4), the enclosure of detached altered, and more highly converted metamorphic schists, within the gneiss, also the occurrence of dyke-like veins of gneiss amongst the schists, would show, that however conformable the original rocks may have been, this relation is rendered more than obscure by the intensity of the metamorphism they have undergone.

Thus, though the gneiss of the two regions may be identical in hand specimens, its diversity of arrangement in the two districts would point either to the occurrence of two different gneiss formations, or else, what is perhaps more probable, to the occurrence of two distinct modes or degrees of metamorphism affecting the rocks within its range differently in each case, coinciding with the stratification in one case, crossing it in the other.

The next point of dissimilarity in the features of these two regions is in connexion with the rocks resting immediately upon the gneiss. In Hazára there are no particular zones having this relation as yet explored; still the schists, &c., of Lachikhun mountain would seem to be a continuous portion of those of northern Kashmir, and may yet be found more palpably resting upon extensions of the Hazára gneiss than has hitherto appeared.

The more than 2,000 feet of blue and black slates, and flaggy slates with blue and fawn-colored sandstones, splintery grayish shales and locally abundant limestones of the Pángi series, scarcely find a counterpart in the Attock slates, though the general description more nearly resembles these than any other portion of the Hazára groups. But the Attock slates have never been observed passing downwards conformably and with intercalation into metamorphic rocks with alternations of gneiss: nor have they been known to contain erratic (*i.e.* travelled) fragments of angular and waterworn gneiss. Hence the Attock slates do not seem to represent the silurian of the Kashmir sections; or if, notwithstanding, they are a modified extension of that silurian formation, they differ in not being conformably associated with the gneiss.

The Panjál series—of black and green slates, sandstones, amygdaloidal rocks, brown sandstone conglomerates containing pebbles of quartzite and slate, white quartzites and sandstones, and below all black slates with pebbles of gneiss and quartzite, granitoid gneiss with bands of slate and quartzite,—seems also to have no closely similar group among the Hazára rocks. The gneiss with bands of slate and quartzite has indeed a certain resemblance to the association of the gneiss and schists of this country, and conglomeratic beds are not unknown among the metamorphic schists; but the whole aspect of the group, despite the entire absence here of the amygdaloidal beds, would seem to possess a rough similarity to the Tanol group, were it not that the latter contains limestones and dolomites, unrecorded in the Panjál series, and it has not the relation of conformable and transitional superposition upon the gneiss. Another difficulty is met with in seeking for the analogues of the Kashmir carboniferous beds in Hazára. The general diversity of the sections in these two adjoining areas prepares one for a difference here also, and I am unable to point to any Hazára group which would

occupy the place of these rocks to the eastward, or which resembles closely any carboniferous exposure in Kashmir, as described by others or seen there by myself.

Mr. Lydekker suggests that local differences in the carboniferous sections of that country may be accounted for by supposing separate areas of deposition. If the differences increase towards Hazára, it would be rash to say the formation is as wholly unrepresented as it appears to be; but I have never found a trace of any of the fossils of this group such as I have met with both in the Salt Range and in Kashmir regions. One unfossiliferous limestone formation may so closely resemble another, that I cannot say whether the massive limestone formation of Gandgarh may not present some identity with that of the Krol group, which I have never seen, but which has been classed with the carboniferous beds of Kashmir, nor yet whether it is similar to the great limestone of the Jamú inliers. The slates of Hazára certainly have a less shaly look than those of the carboniferous group in the Lídar valley-Kashmir.

The occurrence of quartzites, black shales (graphitic or carbonaceous) with nodules of iron ore, and limestones in both the Kiol and the Tanol groups might indicate some identity, but though dolomites are more characteristic of both the latter series and of the infra-triassic of Hazára, and are not uncommon in the Salt Range carboniferous, they do not seem to be strikingly developed in the Kiol group of Kashmir, but rather to be the prominent feature of its trias formation.

The triassic rocks of Hazára are doubtless the same as some of those in Kashmir; and to judge from the description of the latter, it does not appear unlikely that the beds separated in the Sirban series as infra-trias are also included with the Kashmir formation.

For the jurassic rocks of the present district, I find no equivalents recorded in Kashmir; and the same remark applies to the cretaceous formation; though the Spiti shales of the country east and north of the Kashmir region are characteristically displayed in Hazára, with several of their fossils.

The hill nummulitic limestones so extensively developed in Hazára are not known as yet to exist in Kashmir, where, in the fringing zone of limestones outwardly flanking the Pir Panjál, the carboniferous formation takes their place in the general structural sequence.[1] But the upper nummulitic zone of the exterior of the Hazára hills is identical with the Sabáthu zone as determined by Messrs. Medlicott and Lydekker in the Jamú country and near Musaffarábád; I have myself found it on the east side of the Jhelum north of the junction of the Nainsúk with that river[2].

From this brief glance at the want of uniformity between the extensive geological series of the two regions, it appears to follow that considerable diversity of conditions must have accompanied their formation. In regarding this possibility it should be remembered that, though the infra-jurassic unconformity, locally seen in Hazára, can scarcely be declared absent in Kashmir till

[1] In a paper and map in Q. Jl. Geol. Soc. Lond. Vol. XXXIV, p. 347, etc., I have represented this fringing zone as mesozoic as originally shown in Rec. Geol. Sur. Ind., Vol. IX, p. 155.

[2] A different view of the correlation of the nummulitic rocks east and west of the Jhelum has been suggested (Rec. Geol. Surv., India, IX, p. 57), whereby the lower or hill-nummulitic limestone is not regarded as lower than the Subáthu group, but as only a different form of contemporaneous deposits (see also Manual, p. 566).

jurassic rocks are found, there is no record in the Kashmir sections of the very complete break at the base of the Infra-trias group in Hazára. The slight and broken chain of similarities between the series commences with the lithological identity of the gneiss, is most developed, apparently, in the trias formation, and ends with the upper nummulitic tertiary group, or the far more recent Karewah beds. Excepting perhaps the most metamorphosed rocks, all the others present more of disparity than unity, and the reason for this might no doubt be found if the early history of the western Himalayan rocks and ranges were more completely known.

Mr. Medlicott has pointed out (Records Vol. IX, pt. 2, p. 51) that the elevation of the middle Himalayan area to the eastward of this country dates from early or middle secondary times, and that disturbance was specially displayed towards the close of the eocene period; but that from this early secondary date to the most recent (Siwalik) tertiary times no disturbance took place in the region of the Jhelum, that is, in a part of the country to which the present remarks refer. The later observations of Mr. Lydekker on the carboniferous series of Kashmir, indicating separated areas of deposition, and the denudation of the Attock slates of Hazára, besides the evidence afforded by the fragments of ancient gneiss in the Pangi series and rolled quartzite pebbles in the Tanol conglomerates, all these would seem to point to various stages of disturbance and repose of earlier date than mesozoic times in the western Himalayan regions; the absence also of two of the mesozoic formations, so far as distinct records go, in Kashmír, together with that of the great eocene hill-limestone so largely developed in Hazára, may possibly be connected with distribution of depositing areas consequent upon elevation in later mesozoic times. Hence the localization of the central Himalayan disturbance, with regard to the deposition of the later tertiary groups, may bear limitation to the early eocene period; and the discordance between the Hazára and Kashmír series may be due to more or less local or intense disturbances of these mountain regions at various dates from an early palæozoic to the most recent tertiary or even post-tertiary period, if the dip of the Karewahs is attributable to elevation along the Pír Panjál range or subsidence on the opposite side of the Kashmír valley.

10. *Post-tertiary deposits.*—These are not so prominently seen in Upper Hazára, as in the lower country to the south-west, but the Pakli valley and the Hazára plain are filled with detrital accumulations which may be referred to the older kind of alluvial formation. There are also semi-fan-like accumulations in the neighbourhood of Abbottabad, and thence towards Mánsahra, the original continuous surfaces of which have long since been deeply cut into by the torrential streams of the country, indicating a considerable age for these fans.

The detrital accumulations of Lower Hazára, and the Dore river are largely formed of slate debris: and the gneissic or syenitic gravel, found further west towards the Indus, has not been seen beneath these deposits. In parts of the Pakli plain, however, I found a limestone drift sometimes cemented by carbonate of lime, which appears most probably to have come from the southern mesozoic or eocene hills, as it was met with on that side of the plain.

It seems to me very probable that these deposits are of the same age as the

Karewahs of Kashmír; but I would not on that account convey the idea that they were of Siwalik or even of tertiary age.

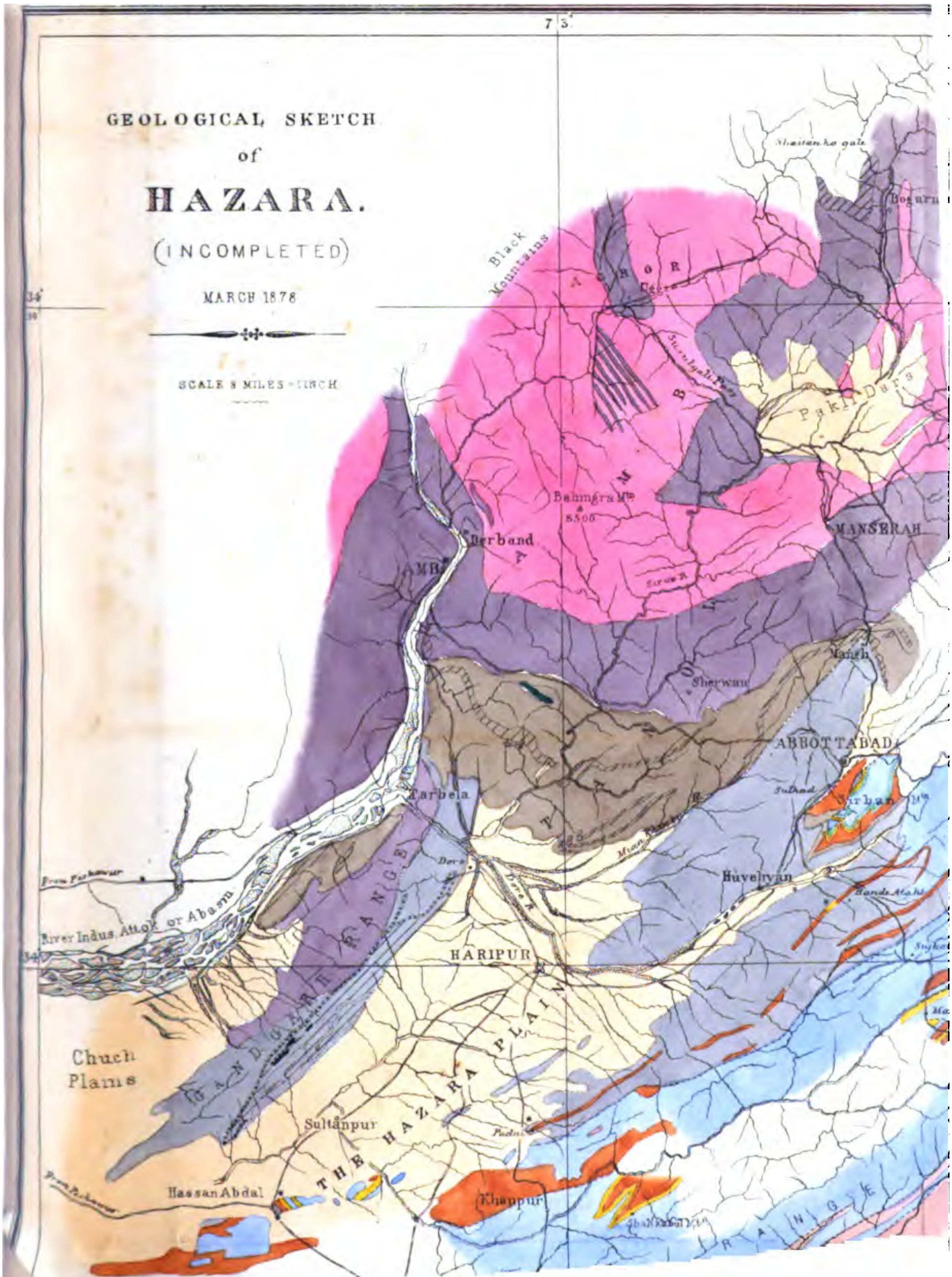
11. *Alluvium and river deposits.*—The alluvium of the Dore and other rivers of Hazára, in low situations, is of light drab silt, not calling for particular notice. Along the Indus the river deposits occur for considerable spaces in the form of terraces, rising to more than 100 feet above the river. The material brought down by this river is also more sandy than in other cases.

A good example of the fan-form of river deposit occurs a couple of miles north of Garhi, along the lower part of a mountain torrent from the Lachikun range. The outlines of similar fans were also seen far above the highest point visited on the Indus, but within the Amb territory, which is difficult of entry without much official correspondence with the political officers.

12. *Northern drift.*—I use this term instead of the more simple one "erratic drift," which would appear to convey to some Indian geologists a closer connexion with glacial geology than is necessary to the purpose. By northern drift then is here meant that influx of travelled masses, which has followed the course of the Indus from the north, and been distributed over large spaces of the Báwalpindi plateau, to a distance (I am informed by Mr. Theobald) of 25 miles from the river. These blocks are easily recognizable all along the Upper Indus, as far as I went, to be the same as those further down its course. They often rest on the terraces, and some of them are of very large size. They are even more numerous along the narrow part of the river valley than in the lower country. This drift of foreign or transported blocks has penetrated from the northwards up the course of the Sírun and Dore discharge, as far as the point where their united valley begins to cut across the end of the Gandgarh range; and at one or two points huge boulders of granite or granitic gneiss seem once to have almost entirely blocked the valley. One of these boulders, between the Turbela-Haripur road and the river Sirun, composed of a fine grained granitoid rock, not the Hazára gneiss, measured $22\frac{1}{2}$ feet × 36 feet × 24 feet, and has a girth of 109 feet.

The boulders are scattered over a considerable space eastward of this stream, where the ground is lower than to the west, and there is a regular drift of well-rounded gneiss blocks, often larger than paving stones, which terminates in two high mound-shaped hillocks at the upper end of the gorge near Dáre village. This disposition of the transported materials shows that many of them may have found a passage through this opening, and floated away to the southward, if rafted by ice, at a time when the Indus ran at a higher level, and most of the lower country may have been occupied by a lake. Some large limestone blocks (from what group derived being uncertain), which occur near Sultánpur on the Haripur—Hasan Abdál road, may be connected with this line of transport.

One remarkable and very large mass of the triassic or supra-trias limestone of Sirban rests perched at about 4,300 feet on the slate hills of the opposite side of the valley above the village of Sulhud. It is from 25 to 35 feet high, and 127 paces in circumference. This mass seems to have slipped from the Sirban mountain at a time when the deep valley between it and that elevation had not been excavated, and its forcible passage northward appears to have somewhat disturbed the edges of the slates forming the surface beneath. I could find upon it no traces of


GEOLOGICAL SKETCH
of
HAZARA.
(INCOMPLETED)
MARCH 1878
SCALE 8 MILES = 1 INCH
Black Mountains
Bogurmang
Pakli Dara
Bahingra Mtn
8500
Derband
MANSERAH
AMB
Sherwan
Mangh
ABBOTTABAD
Sirban
Tarbela
Dora
Haripur
Huvelyan
River Indus, Attok or Abasin
HARIPUR
GANDGARH RANGE
THE HAZARA PLAIN
Chuch Plains
Sultanpur
Hassan Abdal
Khanpur
RANGE

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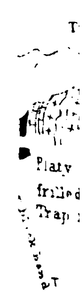

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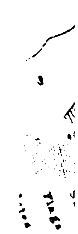
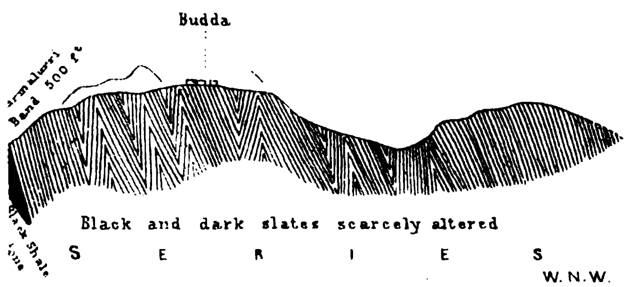
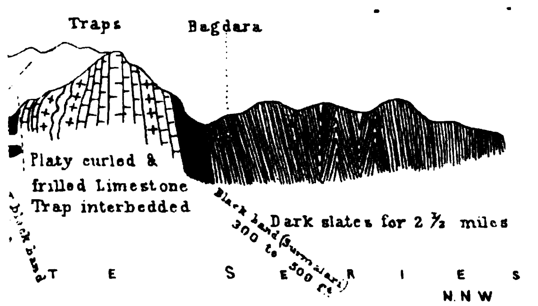
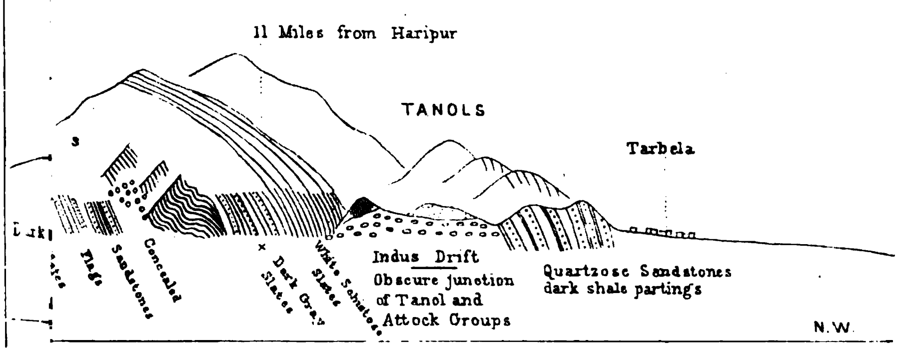


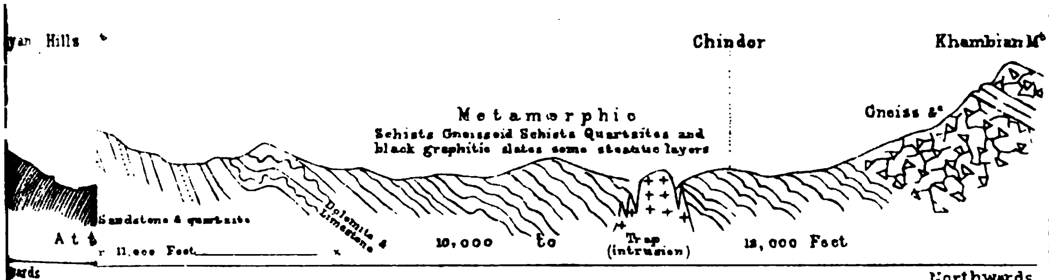




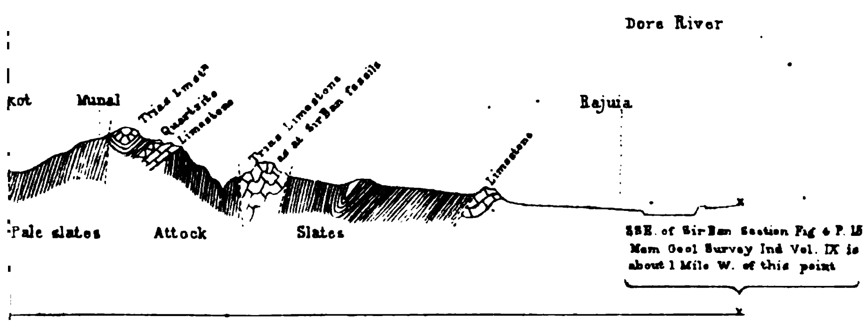
Scales. hor 2in = 1 mile. Vert. 1in = 4000 ft



A GNEISS 22 MILES.



ZARA 15 MILES.



Stone Lith

the action of ice, nor could I see any remains of a moraine in the vicinity. Indeed, these latter evidences of glacial agency have never presented themselves to notice in any part of Hazára I have as yet seen, though Mr. Theobald informs me he has found glacial striæ on one of the large fragments of quartzite, a short way below Turbela. Quartzite of the Tanol group occurs in the immediate locality, but it would be next to impossible to identify one of the stream blocks with the rock of the vicinity, or to prove the former existence of a glacier at the spot from the existence of striation under such circumstances.

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On the geological features of the northern part of Madura District, the Pudukotai State, and the southern parts of the Tanjore and Trichinopoly Districts included within the limits of Sheet 80 of the Indian Atlas, *by* R. Bruce Foote, F.G.S., *Geological Survey of India.*

I.—INTRODUCTORY.

The country to be noticed in the following pages belongs partly to the Madura, Tanjore and Trichinopoly districts, partly to the native state of Pudukotai (Poodoocottah) or Tondiman. Topographically this region may be described as a gently undulating inclined plane rising very slowly westward from the delta of the Cauvery, or the sea board. It is only in the western part that the surface is broken by a few low but steep hills rising in the gneissic area, and by the lines of scarp corresponding generally with the western boundary of the lateritic formations, which occupy by far the greater part of the country now under consideration.

Hydrology.

The hydrology of this area is of very simple character, all the drainage falling in a general south-easterly direction into the section of the Bay of Bengal known as Palk's Bay, by eight principal streams. These streams are, with one exception, quite of small size, the exception being the Vaigai (Vygah) which drains the central part of Madura district. Of the others the two most northerly are really branches of the Cauvery proper; they are the Kori-ár (Coray-aur) and Pámáni-ár (Paumaney-aur), the former running parallel with, but a little distance from, the western boundary of the southern part of the delta, the latter flowing partly just within the delta, and partly within the lateritic area, this latter part of its course being apparently of artificial origin.

The Ikani-ár (Icauney-aur) which falls into the bay to the south-west of Adrampatam rises in the Trichinopoly district, close to Illipur, has a course of only about fifty miles, and is rather torrent-like in its behaviour in wet seasons.

The Vellár (Vellaur) which rises among the hills west of the Trichinopoly-Madura road, in Lat. 9° 25′ and Long. 78° 20′, is also very torrential in its character, rising suddenly in high freshes of short duration which cut away the banks or excavate side channels. According to the map (sheet 80 of the Indian Atlas), the Vellár forks, near the coast, into two branches, represented as of equal size, the northern branch being known as the Narasinga Cauvery. How the topographical surveyors came to show this phenomenon is hard to understand, for it does not exist in nature. The northern branch does not occur as shown, the so-called Narasinga Cauvery being in reality nothing more than an insignificant irrigation channel of such small dimensions that I crossed it repeatedly near Arrantangy without noticing it, though I was looking for it. The southern branch shown in the map is a genuine river, 200 to 300 yards wide and of considerable depth at flood times. Like the other rivers, in this region the Vellár proper flows in a distinctly marked alluvial valley, while the Narasinga Cauvery channel leaves the alluvium immediately below its head, and traverses an unaltered tract of lateritic sand till it reaches the coast alluvium.

Next comes the Pambár (Paumben-aur), which rises to the west of Trimiem (Tirmium) in Pudukotai.

Of the three remaining streams, the Manimut-ár,[1] or Tripatur river, the Serruvayal (Hoop-aur of sheet 80), and the Vaigai, only small portions of their courses lie within our area. The Manimut-ár gathers the drainage of the eastern end of the Sirumallai, a considerable mountain lying to the north-by-east of Madura, and of the hills lying north of Nottam in Madura and Trichinopoly districts. The Serruvayal rises on the high ground east of the Trichinopoly-Madura road near Melur (Mailore), and the Vaigai (Vygah) takes its origin at the head of the great Cambam valley on the eastern side of the Southern Ghâts. The headwaters of the Vaigai drain only the eastern scarp of the ghâts which receives but a very limited supply of rain, the watershed of the whole mountain mass lying in this quarter along the easternmost ridge, hence the river is of much less volume and importance than might be expected.[2]

Geological formations met with.

The geological structure of the area here treated of is as simple as its topographical features, all the rocks met with being referable to but six divisions, which are here given in their descending order:—

6. Soils and subaërial formations.
5. Alluvial formations, marine and fluviatile.
4. Lateritic conglomerates, gravels and sands.
3. Cuddalore sandstones, grits and conglomerates.
2. Upper Gondwána beds. Hard mottled shales.
1. Gneissic or metamorphic rocks.

[1] The name Vershalay-aur given to the Tripatur river on sheet 80 is not recognized by the natives for the upper or middle part of the course. They all call it the Manimut-ár.

[2] A noble project for turning into the Vaigai the surplus waters of one of the principal rivers now flowing to waste in the Cochin backwater has been long and earnestly recommended by the Madras engineers. As the south-west monsoon rains never fail completely on the higher ridges of the ghâts, this project of throwing a vast supply of water across the present watershed would, if carried out, confer an immense boon upon the hot and now too often drought-stricken plains of the Madura country.

The gneissic rocks occupy the western part of the area to be described, and form the highest prominences in it. Amongst them are the line of hills stretching from south of Kolatur (Colatoor), south-south-westward to the Pudukotai-Illipur road, near Annavassel; and several small granite gneiss hills to the south of the Vellár, at and near Trimiem. Between the valley of the Manimut-ár and that of the Vaigai at Madura, a number of hills of small height, but often of very striking outline, occur dotted about at no great distance from the eastern boundary of the gneissic area. Between these hills the general surface of the gneiss country is gently undulating.

The gneissic series.

A considerable part of the surface of the gneissic rocks is occupied by debris of the younger overlying rocks, which have been in greatest part destroyed by the denuding agency of atmospheric forces.

The rocks assigned to the Rájmahál section of the Upper Gondwána system are very slightly exposed, and their contact with the gneiss was not visible, but there is no reason from the analogy of other parts of the Coromandel coast to imagine that their base rests on anything else than the gneiss.

Rájmahál secondary rocks.

The Cuddalore sandstones and grits rest, wherever their base is exposed, on the irregular surface of the gneissic rocks, and are themselves overlaid by lateritic conglomerates, gravels and sands, the relations between the two being extremely obscure from the great petrological similarity of two of the principal members of either group, and from the exceedingly limited number and unsatisfactory character of the sections in which the two series are exposed in juxtaposition.

Cuddalore tertiary rocks.

The total absence of organic remains from both series greatly increases the difficulty of dealing with them. The unconformity of the two groups is inferred from the extensive overlap of the younger of the two. The stratigraphical phenomenon of overlap generally involves unconformity between the formations affected by it, but no positive physical necessity exists that there should be such unconformity in every case, and I have been often strongly tempted to think that in this region it is a case of non-proven. Only one section was seen in which unconformity could be demonstrated, and in several of the best sections there is a passing of true mottled grits, which may belong to either group, into lateritic conglomerates of the most typical character, instances of which will be adduced further on.

The Cuddalore conglomerates, sandstones, &c., appear to be the lower part of one formation; the lateritic conglomerates (mostly), gravels and sands the upper part of one and the same group of rocks; mottled grits of both ages apparently lying in between.

The conglomeratic beds of both groups occur in the western[1] parts of the areas, and generally close to the boundary, at which they are mostly well displayed.

The gravelly and sandy members of the lateritic group occupy the eastern part of the slope, and sink in most cases very gently below the delta of the Cauvery, or the coast alluvium.

The lateritic rocks.

[1] North of our area the conglomerated forms are best seen along the northern boundary of the formation between Vellam and Tanjore.

The lateritic area is divided by the alluvial valleys of the several rivers above enumerated into various patches, of which the most northerly are by far the largest in area. These patches will be found described and named further on.

The alluvia.

Of the alluvia there is very little to say. Only a strip of the southern part of the Cauvery delta was examined. The marine alluvium forms but a very narrow belt in the Adrampatam[1] corner, and the river alluvia are of no great extent or importance. Owing to the great extent of wet cultivation carried on along the various rivers and under tanks constructed across their tributaries, the apparent area of the alluvium has, in the course of many centuries, been largely increased by the formation of artificial alluvial spreads, the boundaries between which and the true alluvia it is in very many, if not in most, cases impossible to determine with any accuracy.

The several rock groups will be most conveniently studied by taking them in ascending order.

II.—The gneissic or metamorphic rocks.

Granular quartzose gneiss.

The prevalent form of gneiss in this region is quartzo-felspathic micaceous granitoid or semi-granitoid gneiss, of pinkish or greyish-pink colour. In texture it varies from a massive, coarse, highly granitoid rock to a schistose gneiss nearly akin to mica schist. A very marked variety which is of common occurrence is a coarse granular quartz rock very rudely bedded and showing numerous small indistinct cavities from which some mineral has been weathered out. In some cases these cavities are filled with an earthy form of dark red or brown hæmatite. The cavities lie in the planes of lamination (coinciding with the bedding), and indeed but for the cavities the lamination would not be visible in most cases. The mass of the quartz is in places not unfrequently very translucent and vitreous in texture.

Hornblendic varieties of gneiss are very much less common in this region, and talcose or chloritic schists were nowhere observed. Ferruginous schists are extremely rare; no example of hæmatite schist was met with, and only one example of magnetite schist.

Finely banded granite gneiss of dense grain occurs here and there largely, as at Tirkornum, west of Pudukotai, and at Ammachattram on the Trichinopoly road.

The line of hills already referred to (page 143) which cuts the Trichinopoly road south of Kolatur, and forms the Alurruttimallai[2] and Narthamallai, consists of banded slightly hornblendic granite gneiss of pale grey color weathering to pale dirty flesh color, and showing characteristic bare rocky masses. Tors are not remarkable, or abundant, but there is much weathering along the lines of

[1] Properly the name of this place should be called Adivira-rama-patnam.

[2] The Alurrutti Mallai or "Man-rolling hill" obtained its name from the practice adopted in former times of executing criminals by rolling them over the great precipice on the south side of the hill. The hill is about 400 feet in height, and the upper part of the great south scarp overhangs slightly.

outcrop and along the plane of an important joint occupying a nearly horizontal position, giving rise to numerous low caves and rock-shelters which are yet used for various purposes by the field labourers. The basset edge of the bedding coincides with the run of the hills, and the dip is westerly. A good specimen of a rock-cut Hindu temple is to be seen on the east side of Narthamallai, and near it are some large holes, now full of water, formed apparently by the weathering out of lenticular masses of more perishable rock.

The Annavassel hills are of very similar petrological character, and so also is the bold rocky mass of the Kudumimallai (Kodemeahmallai), four miles further to the south-west, so called by the natives from a fancied resemblance to the lock of hair worn by orthodox Hindus at the back of their heads.

These hills are almost bare of vegetation owing to their very rocky character, but to the east of Narthamallai is a ridge of the highly crystalline quartzose rock above mentioned, which crumbles by weathering into a coarse grit thickly covered by heavy thorny scrub. Very little rock is to be seen here, and the contrast between the two ridges is very marked. The bedding of this quartzose rock is very obscure, but still traceable by the lines of hæmatitic grains which form discontinuous laminæ. A precisely similar rock, probably the extension of the same bed, is to be seen a little south-east of Pilliur (Pilleoor), eleven miles to the north-east-by-north. No other minerals could be traced in this rock. This band of granular quartzose gneiss shows also strongly to the east of the Annavassel hill, and is doubtless connected with more southerly outcrop of similar rock, as, for example, that on the south bank of the Vellár, close to Kemanur. Still further south this very peculiar variety of gneiss occurs largely, and forms several low hills and ridges which, though nowhere of any height, are yet conspicuous from their light color where not covered by jungle, or from their being crested by narrow ridges of bold blocks and tors. Among these the following are noteworthy: the Neddamurrum hill, three miles north-east of Tripatur, the Manmallai (Munmullay), the north-eastern extremity of a long low ridge which crosses the Tripatur-Sivaganga high road, and may be traced for some thirteen miles to the west-south-west. This, which in parts is crested by a row of striking tors, forms for a distance of fully ten miles a perfectly straight boundary line on which the western edge of the Sivaganga (Shevagunga) lateritic patch abuts.

Another ridge, about 250 feet high and three miles long, lies between two and three miles north-west of the Manmallai, and is locally known as the Yerimallai. In both these ridges the beds have a very high westerly dip, ranging from 75° to nearly, if not absolutely, vertical. Very similar to both these ridges is another which abuts on the left bank of the Vaigai river, about four miles south-east of the town of Madura, and which extends east-north-east towards and apparently joins the row of huge tors which culminates in the Trivadur trigonometrical station hill. Besides the outcrops of the granular quartzose gneiss above mentioned three other occurrences of it should be noted; these are a band occurring about two and a half miles east of Tripatur, which is possibly a continuation of the Neddamurrum beds before referred to. The gneissic rock seen in the inlier south of Trimiem is a similar granular quartzose variety, the crest of a basset edge from which the overlying laterite has been denuded.

Unconnected with any of the above beds is a band of the granular rock at Mallampatti (Mullumputty), forming a low rocky ridge. The bedding in this ease is extremely obscure and doubtful.

Granite gneiss outcrops.

A great show of beautifully banded micaceous granite gneiss is to be seen at Virallimallai, a bold rock crowned with a temple of some note about twenty miles south-west of Trichinopoly on the high road to Madura. The lamination is in parts greatly contorted and "vandyked," and the pink color of the rock, banded with shades of grey and occasional black micaceous laminæ, forms a stone of striking beauty. A similar banded, but paler colored hornblendic granite gneiss is very largely quarried at Puliarpathi (Pooliarputty), four and half miles east of Tripatur. The rock here has, however, undergone much less contortion, and the beds run in a simple ridge coinciding with the strike. These beds appear to underlie the granular quartzose beds which form the Neddamurrum hills above referred to.

Among the more noteworthy outcrops of granite gneiss in the northern part of our area is a band of a pale grey micaceous variety which forms some large tors and bosses at Killumallai (Killumalla) in the northern corner of the bay of gneiss north of the Ikani-ár (Icunney-aur) valley. The general surface of the gneiss in this bay and south of it nearer Pudukotai is much obscured by sandy semi-lateritic soil. Gneiss crops up only here and there, and mostly in detached rounded bosses or "whale backs," as *e. g.*, by the Konanda Kovil bosses, and the extensive "whale backs" north-west of Shembatur.

The rock forming the Vellengoody and Kunamulla trigonometrical stations lying a little westward of the gneissic bay just referred to, and the bosses of gneiss north of Kirnur (close to Kolatur) consist also of micaceous granite gneiss distinctly bedded, especially in the former case. There the bedding is greatly crumpled, and the rock weathers of dirty pinkish color. The Kunamulla rock is more compact, less micaceous and paler in color. It is quarried, and the freshly broken rock is very handsome, banded with pale shades of bluish and whitish-grey.

Peculiar weathering of gneiss under laterite.

Where the gneiss has been directly overlaid by the conglomerates and laterites of the younger series, it mostly shows a great deal of yellowish-red (rusty) ferruginous staining and a peculiar and characteristic gritty roughness of decomposition of the surface not seen where the weathering action has taken place on the long exposed surface.

Other fine outcrops of granite gneiss occur at Suriur (Sooriore) on the boundary of the laterite about seven miles north of Kolatur, and to the west of the last place to the north and south of Nangupatti (Naungooputty), and at Shatanpatti and Rapussel (Raupoossel). There are also numerous fine examples of granite gneiss rocks to be seen on either side of the Vellár valley to the westward of Tirkornum, *e. g.*, at Permanad, Chittur (Shittoor), and Surramulla. West of the latter village is a superb tor of great height, a conspicuous object from considerable distances. East of the village several ridges of gneiss cross the river and divide the alluvial basin into two parts. The high ground south of this near Kotur is crowned by several prominent bosses standing up out of the scrub jungle.

In the southern part of our area several noteworthy ridges of granite gneiss occur, *e. g.*, at and to the north-east of Kilavaladu (Keelaladoo), also at Melur, and last but not least in size or in striking appearance is the ridge known as the Anaimallai (Annamulla) or Elephant hill, five miles north-east of Madura. This last ridge terminates at its southern extremity in a very bold bluff, bearing when seen from various points a very fair resemblance to a huge elephant, a likeness which has given it the name it bears, and connected it with the principal mythology of Madura and the famous temple of Minakshi. It is a perfectly naked rocky ridge, about two miles in length, consisting of grey and pale pink banded micaceous granite gneiss of coarse texture. The dip of the bedding is not distinct; it is, however, mainly westerly, though the northern extremity looks as if it were the remains of an anticlinal fold.

The numerous low rocky hills at and around Trimiem in the southern part of Pudukotai State all consist of coarse, generally micaceous, banded granite gneiss of pale color, varying from pure grey to pinkish or brownish-grey. Tors and great rounded blocks are numerous.

Highly hornblendic gneiss is of rare occurrence in the gneissic area between the Vaigai and the Cauvery; no important beds of it were noted anywhere.

General strike of the gneissic rocks.

The general strike of the bedding trends from west-south-west to east-north-east on the left bank of the Vaigai river, to north and south, or north-by-west south-by-east, in the neighbourhood of Illipur and near the northern limit of our area as Trichinopoly is approached.

A small tract of country over which the strike has a totally different tendency occupies the centre of our gneissic area, and extends from the valley of the Manimut-ár northward to within a couple of miles of the Pambár valley at Trimiem. In the southern part of this tract the strike varies from east-by-south west-by-north to north-west-by-west south-east-by-east; in the central part no well-bedded rocks were mapped, but in the northern part the strike changes from east-west to east-by-north west-by-south.

Magnetic iron bed.

Only one occurrence of magnetic iron in the gneiss was met with; this was about a mile north-east of Mallampatti (Mallamputty), a village in the Pudukotai state nineteen miles north-west-by-north of the town of Pudukotai. Very little of the outcrop is seen, but a good deal of debris of a rich magnetite bed is scattered about the fields a little to the eastward of the Mallampatti granular quartzose gneiss ridge above referred to (page 146).

III.—The Upper Gondwána Series.

Analogy with the geological structure of the more northern parts of the Coromandel coast would suggest as extremely probable the existence south of the Cauvery of representatives of the Upper Gondwána formation; and in fact two outcrops of rocks referable on petrological grounds to that series were discovered underlying the lateritic rocks in Madura district to the north-eastward of Sivaganga. The petrological resemblance of the shales which occur at a small village called Ammersenpatti (not shown in the map) lying near Mudechempatti,

ten miles north-east-by-east of Sivaganga, is very great to some of the hard shales occurring at Sripermatur and Vamávaram; but unfortunately no organic remains could be found, though very closely searched for. The shales are not seen *in situ*, but only as material turned over from the bottom of a small tank south of the village. A considerable quantity, however, was exposed in the bank of the tank in clean condition, so that the color and texture of the rock could be well studied. The prevalent colors are buff and yellow mottled with white. Some quantity was also noted of pink color, ranging to red with a crust of white about $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness along the lines of jointing, which are sharply cut.

Ammersenpatti shales.

About a mile south-east of this spot I came upon a small opening in the heavy scrub jungle where much debris of very sandy hard shale, almost a sandstone, lay mixed up with lateritic debris; this shale, too, bears a strong resemblance to many sandy shales occurring in the northern outcrops of the Upper Gondwána series. No fossils were here observed, nor was the rock seen *in situ*, the surface at that spot being a dead flat showing no sort of section.[1] The spot where the hard sandy shale was seen is passed through by the cart track leading south-south-eastward to Kalliar Kovil.

The petrological resemblance of these shales to members of Rájmahál group (Upper Gondwánas) in the Trichinopoly, Madras, and Ongole areas is certainly far greater than their resemblance to any member of the lateritic series, or of the Cuddalore sandstone group, that I am acquainted with, but in the absence of organic remains, the age of the Ammersenpatti shales cannot be positively determined.

Very faint traces of drab or buffy shale were noted in the bank of a tank-well on the west side of the road to Tripatur, about two miles north of Sivaganga. Only small chips of the shale were found in the mass of kankary lateritic gravel turned out, and no traces of fossils could be found.[2]

Some connection exists also, unless I am mistaken, between some remarkable boulder beds, resting upon the surface of the gneiss in this quarter, and the Rájmahál beds. These boulder beds cover a very considerable surface on the higher ground north-east of Sivaganga, and south-west of Serruvayal. Their limits were not determined owing to the great defects of the map (sheet 80), and to the difficulty of doing any mapping in extensive and thick spreads of scrub jungle in the absence of any landmarks. The boulder beds are best seen along the road leading from Natarashenkottai, north-north-westward to Kolakattipatti (Colacuttyputty). They appear to be due to the action of surf beating on shoals;[3] for not only do many large and well-rounded pebbles strew the surface, but the surfaces of various protuberances of

Boulder beds.

[1] This spot was only examined cursorily, as I came upon it very late in the day when far from camp, and had no subsequent opportunity of revisiting it.

[2] The country round Sivaganga deserves a closer examination than I could give it, as I was seeking to carry the boundary work southward as fast as possible. Failing health and strength, however, compelled me to seek a change which prevented my revisiting these localities as I intended doing.

[3] These boulder beds lie at a higher level than much of the gneissic area to the westward f them.

the coarse granular gneiss are worn and rounded *in situ*. Much coarse and fine lateritic debris rests on and among the boulders. No section was seen showing undisturbed laterite in clear juxtaposition to the boulder beds, but the latter bear greater resemblance to the beds of similar character forming the base of the Rájmahál formations near Utatúr, Sripermatur, and Ongole than they do to any true lateritic conglomerate that I am acquainted with.

IV.—The Cuddalore Series.

The representatives of the Cuddalore series (established by Mr. H. F. Blanford for certain rocks in South Arcot and Trichinopoly districts) which occur in our limits consist of coarse conglomerates, sandstones and grits, the latter passing locally into a rock perfectly undistinguishable from the common laterite which so largely covers the surface in this region. Here as in so many other parts of the Coromandel coast, the slight slope of the country and the very low dip of the rocks have prevented the formation of really valuable natural sections, and civilization has not yet advanced sufficiently to have given rise to any artificial ones of importance. The extension of wet cultivation greatly militates against the formation of deep channels by the different smaller streams draining the country. All are dammed back at many points of their courses, and give rise to the formation of local alluvial flats which only add to the obscuration of the younger rocks, whose relations are therefore generally very unsatisfactorily and imperfectly displayed, so that definite information regarding many interesting stratigraphical points is at present not procurable. The total absence, so far, of organic remains renders the correlation of detached exposures of even similar rocks of great and inevitable uncertainty. These difficulties present themselves saliently in the Tanjore, Pudukotai, and Madura districts.

Thachenkurichi section.

The most northerly section in which rocks, assumedly of Cuddalore age, are to be seen, occurs to the south-east of the village of Thachenkurichi (Thachencoorchy), some six miles north of Gandarakotai (Gundaracottah) in Tanjore district. A fair show of grits and sandstones is here to be seen along the sides of a small winding stream. The sandstones occur in irregular somewhat lenticular patches of dark brown color and considerable hardness. They are overlaid by gritty sandstones mottled pale purple, yellow and rusty red. The upper beds of these are very clayey and lateritic in character. To the south-east of this section lie two small low hills, both capped with thick conglomeratic laterite, but no evidence could be found as to what underlies this capping, the sides of the hills being thickly covered with debris and thorny jungle. The sandstone beds in the stream banks and bed roll about in various directions. West of the village is a broad low ridge of ill-compacted gritty shingle conglomerate, which dips eastward under gritty laterite close to the high road to Pattukotai.

Shingle conglomerate near Pudukotai.

Similar conglomerate occurs resting on the gneiss on the high ground north-east of Pudukotai near Kumupatti (Coomoopatty), and further west near Yeddiapatti.

Along the southern brow of the same high ground overlooking the town of Pudukotai is a line of low cliffs, 12 to 16 feet high, showing conglomerate of

quartz and gneiss pebbles in a gritty, often semi-lateritic, matrix of reddish purple, color, and containing here and there small nests of clay. This conglomerate, which is not very hard, rests on the very irregular surface of the banded (slightly hornblendic) granite gneiss, to which it has imparted a strong yellow stain.

Shenkarai ridge conglomerates.

Among the more southerly conglomerate beds are those met with in the Shenkarai ridge, about eight miles south-by-east of Pudukotai. They are displayed on the western slope opposite Shenkarai village by an extensive series of rain gullies which expose a considerable surface of the gritty conglomerate; but unfortunately do not cut deeply into it. Its base is not seen, but it probably rests directly on the gneiss which shows in Shenkarai tank. The bedding is seen to dip east-north-east or east-by-north at angles of from 12° to 15°. False bedding prevails, but only to a small extent, for so coarse a rock. The conglomerate is of mottled brown to pinkish and whitish, less frequently reddish-yellow color, and tolerably compact with a gritty matrix, including quartz and gneiss shingle, from the size of a cocoanut downward, in moderate quantity. The eastern slope of the ridge [1] is overlaid by the most massive and continuous (sheet-like) bed of lateritic conglomerate that I have seen on the Coromandel coast; it covers a considerable space between Arimullum (Aurmoolum) and Malalapatti, and is itself lost sight of to the east under lateritic sands and the alluvium of the Vellár.

Further eastward, away from the boundary, the conglomeratic character of these Cuddalore beds diminishes rapidly, and very few sections are to be found that penetrate the surface laterite. Where the sub-rock is reached, it is seen to be a grit or sandstone.

Section near Ayangudi.

A second section of the Cuddalore beds forming the Shenkarai ridge was found in the scrub jungle about two miles further south-west and about a mile south-east of Ayangudi. The beds here seen are unlike the Shenkarai beds, they are conglomerates of very coarse texture and rather friable. The matrix, which varies from light red to brown red in color, is semi-lateritic and vermicularly cellular to some extent. The enclosed shingle is mostly large and well rounded; it is chiefly quartzose and all apparently of gneissic origin. The lowest bed seen is mottled and more gritty in texture with fewer enclosed pebbles. The dip is southerly at low angles. Here as at Shenkarai the section penetrates but a few feet vertically.

Section at Ammagudi.

A section in which gritty sandstones are seen peeping out below the surface laterite occurs close to Ammagudi (Aumagoodey) on the left side of the Vellár valley, some four miles north-west of Arrantangy. Brown and purple sandstones occur here of sufficient hardness locally to be quarried into coarse flags. They are exposed in the gentle scarp below the laterite.

Section at Sivaganga.

The last outcrop but one of Cuddalore rocks to be mentioned occurs to the south-east of Sivaganga, about a mile and a half from the town. Here several beds of hard thick-bedded grit crop

[1] The geographical features of this ridge are very inaccurately shown in sheet 80, where it appears of considerable height instead of as a mere low rise scarped only for a short distance at its northern extremity. Extensive scrub jungle covers the greater part of its surface thickly.

out from below the general lateritic covering of the country. In color the rock is dark purplish-grey with brown bandings, and so hard as to be worked by blasting The beds have a north-easterly dip of about 20°. Much diagonal or "false" bedding is seen in the fresh broken specimens of the rock, which is overlaid conformably to the eastward by less compact dark-brown and yellow-brown grits. The hard grits are largely quarried as building stones. Unfortunately no laterite is seen in juxtaposition with the grits, so the local stratigraphical relations of the two rocks cannot be studied.

Section at Perungalur.

The best section of Cuddalore grits of the softer variety occurs about eleven miles north-east from Pudukotai, a little west of the high road to Tanjore. Here the small stream which feeds the Perungalur tank, in descending from the high ground to the north, cuts through the upper laterite beds, and exposes beds of typical grits in many gullies, forming so many miniature canons of very perfect shape with nearly vertical sides, from 12 to 18 feet deep and only 2 or 3 feet apart at the bottom. The grit beds show a rude but distinctly columnar jointing strongly resembling starchy cleavage on a huge scale.

The section here displayed shows the following sequence of beds in descending order:—

4. Black laterite conglomerate, on gravel.
3. Red-brown vermicularly porous conglomerate, passing down into—
2. Brown conglomerate with many pebbles of quartz-grit and older laterite.
1. Grits, pale mottled, generally showing columnar jointing with vermicular tubes and scattered galls of fine clay.

In this section distinct unconformity is seen to exist between Nos. 1 and 2. No signs of organic remains could be traced after very careful search.

A small show of rather soft grit of red and brownish mottled color appears between the boundary of the gneiss and the overlying laterite between Surianpatti (Pothanavial of the Atlas map) and Parembur in the south-western corner of the Tanjore patch.

Mottled grits which on petrological grounds are considered as of Cuddalore age are exposed, in sections of wells and deep tanks, under the laterite conglomerate at Palatur (Pullatoor) and Shuragudi (Shooragoody) in the Shahkotai patch of the lateritic formations (see page 153).

Age of boulder beds.

The boulder beds described above (page 148) as occurring to the north-east of Sivaganga may possibly be of Cuddalore age, or tertiary, instead of Rájmahál age, or secondary, as there is no positive evidence either from the presence of organic remains or speciality of stratigraphical position, but in their facies they are decidedly much more akin to the older series.

V.—The Lateritic Group.

The Cuddalore series is overlaid by the several members of the lateritic series, which vary from hard typical conglomerates through gritty beds to gravels and finally to reddish sands with variable quantities of gravelly pisolitic hæmatite

concretions. The sandy beds occupy the lower slopes near the delta or the band of marine alluvium bordering the coast, while the conglomeratic beds occupy the higher grounds to the west and often overlap widely on to the gneiss.

Sub-division of lateritic area.

The various rivers which convey the drainage of the country to the sea divide the lateritic region into a number of minor areas or patches amounting in all to nine. Their sizes are very unequal as might be expected, ranging as they do from several hundred square miles to only a few dozen or so in extension. Taking them from north-east to south-west the first is the *Tanjore patch*, so called from the fact of its being the southward continuation of the great patch, on the northern edge of which stands the famous old town of Tanjore, five miles beyond the northern limit of the map. This is followed southward of the Ikani-ár by the *Pudukotai patch*, which is divided by the Vellár from the *Shenkarai patch.* South of the Pamb-ár lies another patch of laterite which I will designate as the *Sháhkotai* (Shawcotta) *patch.* South of the Manimut-ár is a small patch which may conveniently be called the *Serruvayal patch.* The most southerly spread of lateritic rocks to be described lies around Sivaganga and should be named accordingly the *Sivaganga patch.* Two of the remaining patches to be considered lie to the westward of the general run of the patches close to the town of Tripatur, after which they may be suitably called the *north* and *south Tripatur patches.* The ninth and last patch lies at the western extremity of the Tanjore patch on the border of the country included in sheet 79; it may for convenience be called the *Nallur patch.* A great number of little patches too minute to be mapped are dotted over the gneiss area at various distances from the present laterite boundary, showing that its former westward extension was considerably greater than it is at present, and that great part of the original deposits has been removed by denudation. Some of the smaller of the far outlying patches have undergone so much change from weathering and reconsolidation that they might almost be reckoned as subaërial formations.

Tanjore patch.

The most remarkable spreads of conglomeratic laterite are to be seen along the western boundary of the areas in nearly every case, but only a few of them need be specially mentioned. To begin with the Tanjore patch. Vast sheets of laterite conglomerate are to be seen to the west and south of Gandarakotai. A little to the north of Suriampatti[1] especially the bare black sheets of rock arranged in terraces with low steps give the country a strange appearance. Where the conglomerate is covered with soil the latter is generally a very hard compact sandy clay of red or yellow (bath-brick) color much marked by sun-cracks, which run in very regular systems and give the soil a tesselated appearance on a large scale. In the presence of water these lateritic soils are fertile, but the high dry downs they are oftenest seen upon are generally waste, and bear but little else than a very low scrub of *Dodonæa viscosa* mixed with a few dwarf *Mimosæ*.

This low *Dodonæa* scrub is quite a feature of the hard lateritic soil tracts, and many instances of it might be adduced. The yellow soil especially assumes

[1] Pothanavial of Atlas map.

not unfrequently very much the appearance of a gritty sandstone without, however, actually possessing sufficient cohesion to deserve the name of rock, though in some cases it very nearly merits being so called. A good example of this may be seen at Nadduveykotai, four miles west of Pattukotai (Puttucottah).

Pudukotai patch.

Passing over to the Pudukotai patch striking spreads of hard typical conglomerate are to be seen in many places near the western boundary and even at some miles distance from it, *e. g.*, at Urriur in the extreme north-west corner of the patch, also nearly all along the left side of the Vellár alluvium valley close down to Arrantangy, and to the north and north-west of Alangudi (Aulangoody).

Shenkarai patch.

The Shenkarai patch contains, as already mentioned above (p. 150), an extensive and massive development of conglomerate in the eastern slope of the Shenkarai ridge and the plain east of it. This great development of conglomerate is continued under the alluvium of the Pambi-ár and re-appears in the Shahkotai patch and is specially well seen at Kilanellikotai (Keelnellicottah), where the walls of the extensive old poligar fort are built of the massive laterite quarried close by. The conglomerate is also admirably seen on the bluff east of Neddengoody, which may be regarded as the continuation of the Shenkarai ridge south-westward. From this bluff which is crowned by a picturesque temple called the Padikása Nadar Kovil, the ridge declines and is lost to the south-west in a high-lying plain of massive laterite extending without a break to Palatoor (Pullatoor). The high ground between Shuragudi (Shooragoody) and Káragudi (Caurgoody) is also covered by a vast sheet of laterite conglomerate, as are also the high ground to the west and south-west of Káragudi near Yalengudi and Kutalur (Coothaloor). The conglomerate is mostly very richly ferruginous for a laterite, and there are abundant traces of a once existing active iron smelting industry. Large quantities of iron slag have been scattered about in many places where now no iron is made.

Shahkotai patch.

Serruvayal patch.

In the Serruvayal patch of lateritic rocks highly ferruginous conglomerate covers a large space between Serruvayal and Kalel (Cullel), also near Páganeri (Pauganary).

Sivaganga patch.

In the Sivaganga patch spreads of conglomerate of considerable extent are frequently met with, *e. g.*, to the north-west of the town, to the east around Natarashenkotai, to the north-west of Kalliar Kovil, and in the northern corner of the patch near Wukur and Tiruvenpatti (Tirroovenputty).

Tripatur patches.

In the two patches north and south of Tripatur the dense and highly ferruginous form of the laterite conglomerate is less developed, and a coarse less ferruginous and less compact form, including very large quantities of gneissic shingle, prevails.

Nallur patch.

The Nallur (Nulloor) patch like the westernmost part of the Tanjore patch consists of a more gritty and rather less compact form than prevails over the spreads above enumerated. The rock is perhaps equally ferruginous, but owing to its gritty character shows a

rougher duller surface with many fewer vermicular cavities. The larger enclosed fragments of older rocks, which consist almost entirely of gneissic quartz, are mostly subangular or angular, giving the rock a breccia-like appearance. Well-rounded pebbles do, however, also occur. A conspicuous example of such a breccia-conglomerate is that occurring to the west of Payakudi in the north-western corner of the Tanjore patch.

The outlying patches of laterite conglomerate resting on the gneiss in the northern part of our area agree generally in character with the gritty variety just described, but those in the south-westerly part are of the more typical form with many vermicular cavities in the more clayey mass. The southern patches when very conglomeratic contain chiefly well-rounded water-worn pebbles, and approach in coarseness to some of the typical conglomerates of median texture in the Madras region, in which stone implements occur. Whether stone implements occur in this southern laterite is a question to which a positive answer cannot yet be given, no unquestionable examples having as yet been found. I did, however, find occasional specimens of coarse quartzose stone which bore a resemblance in shape to various forms of chipped implements common in the more northerly gravels and conglomerates, but the material is so coarse that the chipping could not be considered as positively artificial. The most undoubtedly artificial specimen was a broad axe-head found about a mile north-north-west of Shuragudi in the Shahkotai patch. Occasional fragments of chert derived from unknown sources occur scattered sparsely over the surface of the lateritic conglomerates. Three specimens of this chert appear to be of artificial shape, one is a flake of small size resembling an arrow-head, the second a small prismatic core, the third a thick oblong sharp-edged flake with a distinctly serrated edge to one of its longer sides.

Several large leaf-shaped flakes, almost deserving to be called implements, were found by me between Vellam and Tanjore, only a little distance north of the line forming the northern limits of sheet 80. Two of these were adherent to the surface of the conglomerate and appeared to be genuine exposures *in situ*. They had to be hammered out of the rock.

These large flakes appear to be made of a chert identical with that forming the great fossiliferous blocks lying in the mottled grits occurring to the east of the old fort ditch at Vellam.[1] The small implements above mentioned are made of a much more jaspery-looking variety of chert.

I cannot help thinking that closer search of the shingly lateritic beds such as that at Tallakolum (Tullahcolum), north of Madura, and those occupying so large a part of the two Tripatur patches, would lead to the finding of unquestionably recognizable specimens of chipped implements.

Of the very numerous spreads of lateritic gravelly sands which occupy the eastern part of the lateritic area, the most remarkable is that cut through by the Pámani river at and to the south of Manárgudi in Tanjore district, which also extends close down to the sea-coast at Adrampatam.

[1] See Mem. G. S. I., IV, p. 36. A fresh collection of fossils from these chert rocks was made in 1878 to supply, as far as possible, the place of the collection lost on its way to Calcutta by the wreck of the *Aurora* in 1860.

The section of these sands in the bank of the Pámani-ár at Kara-ká-kád (not in the map), a little village about a mile north-east of Painganád (Pynganaud), shows the following succession of beds:—

Kara-ká-kád section.

Local alluvium	... ...	1½'—2'
Gritty sands	... ...	2'
Ferruginous gravel with quartz fragments	...	4' (exposed).

Character of the ferruginous gravel.

The gravel is formed by accretion of quartz grains (sand) with a brown hæmatitic cement into rudely rounded lumps generally about the size of a hazelnut. These lumps are here, and generally in the eastern part of the lateritic area, unglazed and dull in appearance; further west, however, the lateritic gravel is generally glazed and externally smooth even when fracture shows the interior to be gritty. The shiny glazed form is also seen in the lateritic sands of this part of the country, and a half glazed form is not uncommon.

Where bare or but thinly covered with vegetation, the surface of the bands is often covered by thin sheets of this ferruginous gravel, from which the sandy and clayey portions of the original bed have been removed by fluvial action. Where the thickness of the gravel beds has become considerable, subaëreal consolidation not unfrequently sets up, specially where the glazed form of the gravel occurs.

Passage of lateritic sands into grit.

In the northernmost part of the Tanjore area within sheet 80, in the tract lying along the high road from Tanjore to Adrampatam, the lateritic sands are seen to pass down into typical soft grits of pale color containing but little ferruginous matter. These grits may be seen at the villages of Kovilur (Coviloor), Karkankotai (Curkancottah), and Ulur (Woolnoor). The sections, which are only in the sides of wells, are neither deep nor clear enough to show the relations of this pale grit with the undoubted Cuddalore beds.

Loamy beds.

The whole of the eastern part of the lateritic area is not everywhere covered by sandy beds: some considerable tracts, *e.g.*, around Pattukotai (Puttucottah) are occupied by rather hard red loam containing variable and sometimes considerable quantities of lateritic gravel of the non-gritty glazed variety. This hard red loam graduates into the sandy form imperceptibly. It is generally confined to the higher grounds.

The bottoms of the shallow valleys which drain the area occupied by the softer members of the lateritic series are frequently occupied by swampy ground or by small quicksands, very unpleasant to a guideless rider, and the higher parts are not unfrequently very sandy.

Flora of lateritic region.

The flora of the lateritic area differs in the eastern parts considerably from that of the gneissic region and of the high-lying area covered with hard conglomerate or quasi-baked clayey soils. The sandy eastern parts support very extensive plantations of cashew-nut trees (*Anacardium occidentale*), with very frequent clumps of bamboo and pandanus. *Calophyllum inophyllum* occurs also more frequently here than in any other parts of Coromandel coast that I am acquainted with. The jack tree (*Artocarpus*

nitigrifolium) is also cultivated to a very great extent all over the lateritic area, but some of these trees are common on the gneissic area.

Of minute plants one of the most characteristic, which occurs in immense numbers in low lying damp sandy flats, is a small *Drosera* or sundew, though elsewhere a very rare plant in the low country. A zoological peculiarity of the lateritic sandy region is the great frequency of a large *Spongilla*, or freshwater sponge, in many of the shallow rain-fed irrigation tanks. Nowhere else have I noticed this sponge to be common or to attain to anything like the size it does in this quarter.

Alluvial Formations.—The alluvial deposits coming within the scope of this paper are of small extent, as only a small section of the south-western corner of the Cauvery delta was examined, and the alluvia of the various small rivers traversing our area are very limited.

The western part of the Cauvery alluvium is formed of a black clay, apparently a true regur, becoming gradually sandy as the sea is approached. No section penetrating through this black clay was seen within the limits of sheet 80, but a fresh excavation for the foundations of a new sluice branching off from the Pamani-ár just within the area of sheet 79, on the road from Manárgudi to Neddamangalam railway station, revealed a bed of very stiff blue clay full of small kankar (gravelly tufa).

The alluvia of the smaller rivers is generally a whitish mixture of sandy clay with lateritic pellets and small debris of quartz and gneiss. The flats are often slightly swampy, or barren, and unproductive from the saline matters enclosed. An exception to the whitish alluvium is offered by the alluvium of the Manimut-ár below Tripatur, where low cliffs of reddish loam form the river banks for a couple of miles or more above Neddarakotai. The alluvium of the Vaigai appears to be generally sandy, but no sections were seen, and from centuries of wet cultivation the whole surface must be looked upon as really "made ground."

The coast alluvium near Adrampatam is generally clayey near the surface and edged with a narrow strip of ill-defined sandhills. No sections of the coast alluvium were seen.

Soils.—The soils depend almost everywhere on the underlying rocks for their character. Red and reddish sandy soils abound. Black soil is not at all common. It occurs largely only over the western side of the Cauvery delta, and under a few important irrigation tanks where it must be regarded as of artificial origin. Whitish clayey soil very similar to the pale alluvia of the large streams is met with in many valleys of the eastern lateritic areas, and, as above mentioned, often forms small treacherous quicksands most disagreeable to the rider.

Where the conglomeratic laterite occurs two forms of soil prevail, both of them hard clayey sands, the one of bright red, the other of pale yellow (bath-brick) colors—often approaching in texture to true sandstones. Many large spreads of these occur covered with low scrub of *Dodonæa viscosa* and a few dwarf mimosæ and other thorny bushes, *e. g.*, on the high ground to the south of Gandarakotai in the Tanjore patch, and again on the high ground north-east-by-east of Alangudi in the Pudukotai patch. The surface of the soils is

often covered with light wreaths of grit and sand collected by the prevailing winds.

The red soil is the more common form, but both it and the yellow variety show frequently on the hardest parts of the surface a semi-metallic-looking blush of bluish-black color.

Over the lateritic bands the soil is generally a nearly pure, less frequently somewhat clayey, sand.

Real blown sands were very rarely noted within the limits of sheet 80 as far as the survey extended; those in the little strip of coast examined in the Adrampatam corner of Palk's bay are hardly worth noticing, and the same may be said of a few low hillocks on the bank of the Vaigai river near Tirupavanam (Trippawanum). The most notable accumulation of sand raised by wind was seen between Vadakur (Vuddacoor) and Pinneyur, three and half miles south-west of Ortenád Chattram (Mootooaumaulpooram of the Atlas map). The hillocks here are of very small extent, but rise from 15 to 16 feet in height; they are limited to a very small superficial area.

Economic Geology.—Few districts even in the poor region of Southern India are so extremely destitute of valuable minerals as the country dealt with in these pages. Building-stones, road-metal, and kankar for lime-burning are at present about all the material collected for economic purposes, with the exception of a little impure salt and saltpetre.

Iron used to be smelted in some quantity from ores obtained from the lateritic conglomerate beds as testified by the quantities of iron slag scattered over the country and here and there accumulated in large heaps. Of late, however, this industry seems to have died out entirely, for I could not hear of its being now followed anywhere, nor did I come across any villages in which smelting furnaces were still in operation.

The compact richly ferruginous laterite conglomerate furnishes endless material for rough building purposes, and is even carefully cut and dressed for better class buildings now put up at various places by the rich Natukotai Chetties, a caste of rich traders and soucars who are buying up much land in many villages on the lateritic area and building palatial houses in every direction, besides tanks and temples. Many old buildings of importance have been built of this stone, *e. g.*, the great fort at Kilanelikotai and the fort at Arrantangy. The laterite of the Shenkarai patch and the northern part of the Shahkotai patch yields the largest and apparently the most reliable and homogeneous blocks I have seen quarried anywhere between Cape Comorin and the Kistna river.

Of gneissic rocks the Puliarputti banded gneiss is the most largely used. The great quarries four miles east of Tripatur are largely worked for blocks of all sizes, up to nearly 30 feet in length. The stone is in great demand because of its beauty and moderate price owing to its being easily quarriable. Large pillars about 12' by 3' by 1' 6" roughly dressed for the gates of pagodas or mantapams cost only Rs. 30 on the spot.

Very handsome granite gneiss is quarried at Tirkonum, west of Pudukotai, and at Kunamulla trigonometrical station hill, fourteen miles to the north. The granite gneiss at Virallimallai, twenty miles south-west of Trichinopoly

on the Madura road, could yield stone of very great beauty if required (p. 146). Less handsome, but very useful stone is quarried from the granite gneiss rocks occurring at Trimiem in Pudukotai State, and at foot of the Anaimallai near Madura (p. 147).

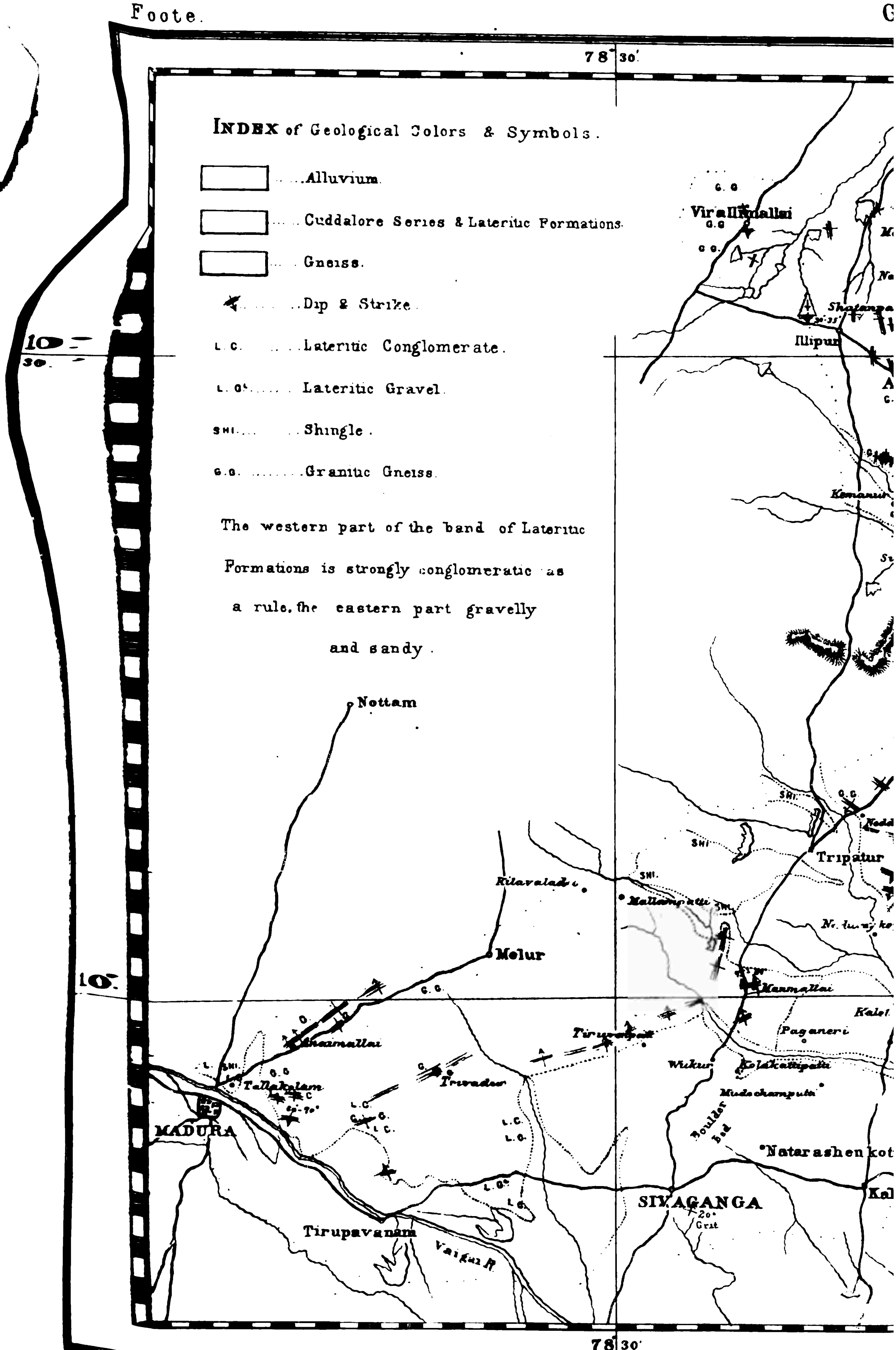
My stay at Madura was too limited to allow of any enquiry into the question of the localities which yielded the splendid black hornblendic rock forming the noble pillars to be seen in Trimal Naik's palace, one of the most remarkable buildings in India. The quarries which yielded this stone and the hornblendic rock carved into the many bold striking figures and statues in and about the great Madura pagoda were not among those seen by me, and doubtless lie beyond the limits of the gneissic area surveyed.

Some of the finest and boldest carvings, both of statues and scroll work that can be met with in Southern India, are to be seen at the Avadiar Kovil, or temple, in the southernmost corner of Tanjore district. The great mantapam in front of the temple gate is an architectural work of great beauty and noble proportions, far better worth photographic illustration than many other buildings that have been made known to the public. Unfortunately it is so much off the beaten track that very few know of it, and hardly any one visits it. The stone used is said to have been brought from Trimiem and Tirkornum, but is more hornblendic than any of the rocks seen at those places.

The great temple at Manárgudi, on the western edge of the Cauvery delta, is largely built of gneiss from an unknown locality, but which must have been brought a distance of fully fifty miles, supposing it to have come from the very nearest quarries, those of Mammallai, eight miles east-south-east of Trichinopoly. These quarries may well have yielded all the slightly hornblendic pale stone used at Manárgudi and also at the great Tanjore temple, excepting, probably, the famous great bull and a few other large monoliths of much more hornblendic character. It is not known for certain where these were quarried, but I suspect they came from a bed of very hornblendic gneiss at foot of the Pachamallais near Perambalur in Trichinopoly district. My reason for suspecting this is, that when at Tirumanur in 1878, on the left bank of the Coleroon to the north of Tanjore, I saw several very fine monolithic blocks of dark black hornblendic rock lying on the river bank. These were said to have been brought there by the late Rajah of Tanjore from a quarry close to Perambalur to be used for a temple which was never built. This very black stone much more resembles the black monoliths in Tanjore pagoda than anything yielded by the quarries south of the Cauvery.

Great complaints are made in the southern taluqs of Tanjore district of the want of proper road-metal for the roads in those very sandy regions, but this difficulty might be largely met by screening out the lateritic gravel which occurs in large quantity in the sands in very many localities along the Manárgudi and Adrampatam roads.

Foote.



Stone by S. ...

ROUGH NOTES ON THE CRETACEOUS FOSSILS FROM TRICHINOPOLY DISTRICT, COLLECTED IN 1877-78, *by* R. BRUCE FOOTE, F.G.S., *Geological Survey of India.*

The following notes have reference chiefly to the fossils I collected in 1877 from the Utatúr and Arialúr groups, at Utatúr, Maravatúr, Odium, Arrialúr, and Mallúr, which alone received any careful examination. The fossils from the other localities received as a whole merely cursory inspection while being arranged for numbering. The term "new species" that will be found used here and there implies only that the fossil does not agree with the figures and descriptions of species described by Dr. Stoliczka in the Palæontologia Indica.

Sponges.—A special feature of the collection is the large number of sponges it contains as compared with the far larger collection originally made at the time the geological survey of the district was being carried out. Dr. Stoliczka figures only two, which he refers to the genus *Siphonia.*

Among the sponges collected by me are numerous specimens belonging to the very important and characteristically cretaceous family of *Ventriculites.* These were found mostly weathered out of a bed of limestone south-west of Maravatúr (*Loc.* 10), very low down in the Utatúr group. They belong apparently to three species, or varieties, of different form and texture (*e.g.*, Nos. 5, 6, 7, 18—20, 45 and 49). Many show the characteristic network extremely well (*e.g.*, No. 49).

With these *Ventriculites* occurred several specimens belonging to another group (*? Spongites*), showing quite dissimilar texture (Nos. 8 to 14).

The same bed of limestone, which forms a small knoll, yielded a considerable number of other fossils, all of which were collected from a very limited space, only a few dozen square yards in extent. The most numerous of these were spines and plates of Cidarids; Belemnites were found in considerable numbers; a few small Ammonites, with other shells and corals, were also obtained. The large Pecten (No. 50) came from another bed rather nearer to Maravatúr.

Naicolum "sponge bed."

A numerically much larger number of sponges, of a small cup-shaped group, was obtained from one of the lowest beds of the Utatúr group, exposed at head of a gully opening eastward, a few yards east of the old Madras road, $\frac{3}{4}$ths of a mile south-south-west of Naicolum (*Loc.* 3). These were found with a great number of other fossils on the weathered outcrop of an argillo-calcareous sandstone. With the cup sponges was one specimen of a mamillated species (No. 278). A large specimen (No. 32) of clavate form was also found weathered out of the same bed, but originally derived without doubt from the coral reef limestone at base of the Utatúr group.

Two other sponges were obtained from the middle part of the Utatúr group exposed north and north-west of Odium (*Loc.* 21). Of these, which are numbered 14 and 15, the latter appears to be a *Siphonia.*

Vertebrate remains.—A number of large vertebræ, apparently reptilian, very like those of *Ichthyosaurus,* were found by me in the clays north-east of Utatúr. Nine out of sixteen lay together, in apposition, when I found them, but were

unfortunately disturbed, before I had time to number them, by an officious collector, in direct contravention of his orders. The others had been washed down the slope of the rain gully in which they were exposed, but they all doubtless belonged to the same individual. I have had no opportunity of comparing them with figures of known *Ichthyosaurus* vertebræ. They are numbered *O*47—63.

The seven shark's teeth (marked *O*43) belonged, I believe, to the shark that yielded the large vertebræ Nos. 34—40. They were all found quite close together, weathered out of one of the large earthy ferruginous concretions, at only a short distance from the large reptilian vertebræ.

A novelty among Utatúr fossils is the *Ichthyodorulite* (No. 46*O*).

Mollusca.—The chief novelties are several *Rhyncholites*, or mandibles of Nautili, belonging to two if not to more species. Three of small size, not well preserved, were obtained from the outcrop of the "sponge bed" (*Loc.* 3). Two others, one large, of rather different form (*Nos.* 24 *and* 25*O*) were found in the Utatúr clays. Two other peculiar bodies (*O* 26 *and* 27) bearing some resemblance to *Rhyncholites*, but both apparently somewhat broken, were also found in the Utatúr clays.

Rhyncholites.

Embedded in the clay filling the body-chamber of a nautilus from Utatúr is a singular body (No. 23*aO*), somewhat fruit-like in appearance, that I was unable to determine. I wish to draw special attention to it.

Fruit-like body.

From the same locality (*O*) came what appears to be a new Belemnite (*O*28) of short squat form and blunt pointed; quite unlike any figured in the Palæontologia Indica. It is much the rarest form of all occurring in the Utatúr clays.

Belemnites.

The long, thin, sharp pointed Belemnite (No. 31) occurs chiefly in the higher clay beds.

Interesting specimens of Belemnites are numbers 67, 68, and 69 from Odium (*Loc.* 21), parts of phragmocones, the latter of very large size. No. 70 shows great part of the pro-ostracum.

Among the *Ammonitidæ* No. 88, from Anapadi (*Locy.* 15), may be a new species, for it does not agree with any of those figured by Stoliczka.

Ammonites.

Of the rare form *A. kalika* founded by Stoliczka on a unique specimen from the Arrialúr beds east of Utakoil, a second example (*OK* 16) was found by me at the same place. It is in good preservation.

Of another rare form, *A. xetra*, based by Dr. Stoliczka on two specimens from Cunum, a third example was procured at the same place. It is a young specimen and unfortunately much broken (20*o* 55).

An apparently new species of *Turrilites* with very delicate transverse ribbings on the whorls was found by me west of Arrialúr (*Loc. A*, No. 16.

Turrilites.

No. 18 from the same locality would also appear to be a new species of *Baculites*, unless it be part of a *Ptychoceras*.

Baculites.

Of the *Gasteropoda* that I had time to examine and to compare with Stoliczka's figures in the Palæontologia Indica, several, which I enumerate below, appear to differ to a considerable extent, and may very probably be new species or varieties—

Gasteropoda.

Nerinæa, sp.	Locy. 11[1]	No. 4
Scala, "	" A[1]	" 141
Cancellaria, "	" "	" 149
Velutina ?	" "	" 150
Sigaretus ?	" "	" 150*a*
Natica, sp.	" "	" 151
Cantharidus ?	" "	" 156
Thylacodes	" "	" 159
Trochactæon ?	" "	" 160
Dentalium	" "	" 163
Fasciolaria	" 21E[1]	" 32
Solarium	" 24[1]	" 63

[1] Locality 11 is north and north-west of Maravatúr.
" A west of Arialúr.
" 21E north-east and west of Odium.
" 24, reef in stream half a mile below Veraghúr.

Among the *Pelecypoda* the following forms appear to be new, *i. e.*, unfigured, by Dr. Stoliczka:—

Pelecypoda.

Ostrea, sp.	Locy. 11	No. 14
Pholodomya ?	" A	" 10
Panopæa, sp.	" "	" 13
Tellina, "	" "	" 27
Trigonia, "	" "	" 46
Avicula, "	" "	" 61
Ditto, "	" "	" 62
Mya, "	" 21[1]	" 47
Exogyra, "	" 27[1]	" 73

[1] Locality 21 is north-west and north of Odium.
" 27 is east of Karapády.

A singular plicated tube of doubtful molluscan or annelidan origin is specimen No. 24, from the coral reef limestone near Naicolum (*Loc.* No. 2).

Plicated tubular shell.

Echinodermata.—The small echinoderm No. 5, from the "Sponge bed" south of Naicolum (*Loc.* 3), appears to be new, as does also the encrinoid joint No. 4. The same may be said of an encrinoid joint found in the Utatúr clays (*O.* No. 64).

Bryozoa.—Two very beautiful small Bryozoa, Nos. 129 and 130, were obtained by me from the "Sponge bed" (*Loc.* No. 3). They are quite different from anything figured in the Palæontologia Indica.

Corals.—Considerable numbers of a very delicate little cup coral (*C. E.* Nos. 1—65) were found in white clays half a mile east of the Cudicád-Cullpády road, and rather nearer to the latter place. They appeared confined to a very small area, and were not met with elsewhere.

Plants.—Plant-remains, fossil-wood excepted, are very rare in the Trichinopoly cretaceous beds, but a few obscure specimens were obtained, *e. g.*—

An impression of a longitudinally ribbed stalk found at Seraganúr (S. No. 15).

A minute piece of a cycadeous (?) leaf in an indurated clay nodule from the Utatúr beds north of Cudicád (C. No. 3).

Minute fragments, apparently of cycadeous leaves, are traceable in some parts of small clayey nodules from the Utatúr beds (Nos. 67—72*O*).

Locality No. 2.—The collection of fossils obtained from this patch of coral reef limestone is a very important addition to the fauna of this rather obscure formation, which yielded but little, if I mistake not, to earlier searches. My success in procuring specimens was due to the limestone having been quarried to some extent quite recently. All the specimens found I obtained from the quarry chips, with only one or two exceptions.

Locality No. 3.—This locality, which does not appear to have been known to Mr. Blanford as a rich hunting ground, shows three sets of fossiliferous beds, the lowest being coarse calcareous gritty beds with a few fossils and many washed-up pebbles of the coral reef limestone, also some masses almost deserving the name of boulders of the same rock. On these rests the "Sponge bed," an argillo-calcareous sandstone. On this again lies a clay bed with large indurated nodules, containing occasional Ammonites and Nautili with a few other shells. These are easily distinguishable by their light color, pale yellow or buff, while the "Sponge bed" fossils and those from the lower beds are mostly of a distinctly brown color.

The fossils from the "Sponge bed" were nearly all found within a very small space of ground, on the very basset edge of the beds, or the upper two or three feet of the gritty talus. The fossils met with, beside the sponges, rhyncholites, echinoderms and encrinoid joints already mentioned, were Cidaris spines, Belemnites, small Corals, Bryozoa, Serpulæ in great variety and numbers, large numbers of *Tubulosteum callosum*, numerous Gryphæa and Oysters, and lastly, a number of small shells, both Gasteropoda and Pelecypoda, not forgetting a few small Ammonites. I do not recollect any other fossil locality in which I obtained so rich a collection, in an equally small space, reckoning the richness by the number of species.

Locality "*O.*"—Mr. Blanford, in his Memoir on the cretaceous rocks, speaks of the small clay nodules near Utatúr as hardly ever containing any fossils. This statement is, I think, rather too strong, and calculated to deter future collectors from searching one source of valuable fossils. My own experience is, that they are not common in the small nodules, but still common enough to encourage search. I got several (eleven I think) in a morning's general search, without devoting more than half an hour specially to breaking nodules. Two of the eleven are certainly valuable specimens, the rhyncholite-like bodies referred to above (Nos. 26 and 27).

NOTES ON THE GENUS SPHENOPHYLLUM AND OTHER EQUISETACEÆ WITH REFERENCE TO THE INDIAN FORM TRIZYGIA SPECIOSA, Royle (*Sphenophyllum trizygia*, Ung.), *by* OTTOKAR FEISTMANTEL, *M.D.*, *Palæontologist, Geological Survey of India.*

Last year a peculiar discovery was announced by Mr. Stur, at Vienna, on the relations of certain genera of Equisetaceous plants in the coal-formation. The observations refer also to the genus *Sphenophyllum;* so it will not be out of place to note this discovery, and to add some remarks on those plants with reference to the Equisetaceous plants in the Indian coal-beds, especially to *Trizygia speciosa.* The most common genera of the *Equisetaceæ* in the carboniferous formation are those which were described as *Calamites* (Suckow, 1784), *Asterophyllites* (Brongniart, 1828), *Annularia* (Sternberg, 1822), and *Sphenophyllum* (Brongniart, 1828). These were all described as distinct genera.

In 1852, however, Professor Ritter von Ettingshausen,[1] placed the genus *Asterophyllites*, as "*rami et ramuli,*" to *Calamites*, although, as it appears, there was no direct evidence for the proceeding. In 1869 Mr. W. Carruthers[2] united all the three genera, *i.e.*, *Asterophyllites*, *Annularia*, and *Sphenophyllum* to one group under the name *Calamites*, considering them as three different forms of foliage of this one genus, although, as it appears, the author had no direct evidence for this theory.

Professor Schimper (1869) placed the genus *Asterophyllites*, which he named *Calamocladus* under the heading "*rami et ramuli foliosi,*" to *Calamites;* but *Sphenophyllum* and *Annularia* remained independent genera.

Professor Weiss (1871) again[3] urges the independent nature of all the genera abovenamed; and so does Professor Heer, even in his recent publications.

In 1874 it was shown by Professor Williamson,[4] who based his conclusion on the microscopical structure, that *Asterophyllites* and *Sphenophyllum* were very closely related genera.

In 1876 another systematical place was assigned to *Sphenophyllum* by Professor Schenk,[5] who arrived at the conclusion that *Sphenophyllum* is more related to the *Lycopodiaceæ* than to the *Equisetaceæ.*

To this Mr. Stur wrote a reply under the title "Ist das *Sphenophyllum* in der That eine Lycopodiaceæ,[6]" where he endeavoured to show that the systematical position of *Sphenophyllum* is with the *Equisetaceæ.*

So stood the case till last year, when Mr. Stur announced his discovery,[7] which was as follows: On a slab of shale were found several branches of an *Asterophyllites* with branchlets, which showed the foliage of a *Sphenophyllum* (*Sph. dichotomum*), and had a fructification of the kind of *Volkmannia*, (Stur). On other

[1] Steinkohlenflora von Radnitz, Abh. d. k. k. geol. Reichsanstalt, Vol. II, p. 24.

[2] In Seeman's Journal of Botany, 1867.

[3] Fossile Fl. d. jüngst. Steinkohlf. und des Rothliegenden, &c., pp. 107, 108, 2nd Part.

[4] Philosoph. Trans. R. Soc., Vol. 164, p. 41 *et seq.*, 1875.

[5] N. J. f. M., 1877, p. 435, Refer.

[6] Jahrb. d. k. k. geol. Rchstlt., 1877, Vol. XXVII, pp. 7—32.

[7] Verhandl. d. k. k. geol. Reishsanstalt, 1870, p. 327. See N. Jahrb. f. Min., &c., 1879, pp. 256 and 260.

specimens the same *Asterophyllites* is said to have a fructification of the kind of *Bruckmannia* (Stur), and to be preserved in such a manner, that it has to be considered as branches of *Calamites*, preserved on the same slab of shale.

The conclusions to which Mr. Stur arrived are that *Sphenophyllum* is no peculiar genus, but belongs to *Asterophyllites*, and both *Asterophyllites* and *Sphenophyllum* are branches of *Calamites*.

Professor Williamson and Professor E. Weiss have published their opinions about this remarkable discovery.[1]

Professor Williamson considers the connection of a *Sphenophyllum* and *Asterophyllites* as quite probable, and finds in it the confirmation of his own views on the relation of *Asterophyllites* and *Sphenophyllum*; but he thinks it impossible that both these genera should be the branches of a *Calamites* of the ordinary type, as it occurs in England, the structure of *Asterophyllites* and *Sphenophyllum* being totally different from that of *Calamites*.

Professor Weiss concurs with Professor Williamson as regards the impossibility of *Asterophyllites* and *Sphenophyllum* belonging to *Calamites*; but he is not prepared to accept the view that all *Asterophyllites* and *Sphenophyllum* should be closely related, and he finds a distinguishing character in the fructification. He says (*l. c.*), p. 264:—

"From the admission that branches with the appearance of *Asterophyllites* and *Sphenophyllum* may be found on the same plant, as observed by Stur, it would not at all follow that *Asterophyllites* in general is identical with *Sphenophyllum*, and still less that both these should be identical with *Calamites*."

Professor Weiss therefore seems to allow that *Asterophyllites*-like branches may be found with *Sphenophyllum*-like branches on the same plant, there being also two other genera, *i.e.*, *Cingularia* and *Bowmanites*, which have *Asterophyllites*-like stalks. *Sphenophyllum* and *Asterophyllites* of the carboniferous formation also agree in the arrangement of the leaves, all being arranged in whorls. But still he maintains the independence of *Sphenophyllum* in other cases.

If we now turn to the Equisetaceous plants in the Indian coal-beds, we find especially three forms—

Phyllotheca (not very frequent, and in the Raniganj group only).

Schizoneura (rare in the Barakar group, but very numerous in the Raniganj group).

Trizygia (in both the Barakar and Raniganj groups).

Besides these many other stalks, without certain affinities.

The genus *Phyllotheca* is known from the lower (palæozoic) coal-beds, the Newcastle beds and Wianamatta beds in New South Wales, and from the upper mesozoic beds (Bellarine-beds) in Victoria; from jurassic-beds in Siberia (Altai, Lower Tungutska river[2] and Eastern Siberia), and in Italy.

[1] N. Jahrb. f. Min., 1879, pp. 256 and 260.

[2] The formation with fossil plants in these two districts is jurassic, according to the last communication of Prof. Schmalhausen (Bull. d. l'Acad. des Sc. d. St. Petersbourg, Vol. XI, pp. 77-81), containing *Phyllotheca*, *Sphenopt. anthriscifolia*, *Asplenium whitbiense*, var. tenue, *Zamites inflexus*, *Podozamites eichwaldi*, *Ctenophyllum*, *Rhiptozamites* (Nöggerathia), *Czekanowskia rigida*, *&c.*

There is no representative of this fossil plant in the carboniferous beds of Europe, the leaves being joined to an undivided spathe at their base, and free in the upper part.

As regards the other two, *Schizoneura* and *Trizygia*, I find the following remark about them in Grand'-Eury's great work on the carboniferous flora in France,[1] page 404:—

"Il faut cependant bien reconnaître que certaines plantes des terrains secondaires inférieurs ont des attaches avec celles des terrains primaires ... ... le *Trizgyia speciosa* de Royle, resemblo à un *Sphenophyllum oblongifolium* qui deviendrait beacoup plus ample; les *Schizoneura* du grès bigarré y suppléeraient aux *Asterophyllites*."

As far as *Schizoneura* is concerned, this thesis seems probable, this genus also having linear leaves, in whorls, which are however in most of the cases joined to two broader, encircling leaves, which morphologically originated from a spathe (sheath), to which all the leaves are joined in the beginning of the growth of the plant.

With *Trizygia* we will have to admit a slight modification. *Trizygia* was first proposed by Royle on account of the arrangement of the leaves, always six in three pairs on one side of the joints; this character is completely constant in all the specimens hitherto observed; the species was *Triz. speciosa*.

Mc'Clelland (1850) described it as *Sphenophyllum speciosum;* Unger (1850) as *Sphenophyllum trizygia.*

I myself followed Unger's example in my first notices on the Damuda flora (1876); but after these various researches on the nature of the carboniferous *Equisetaceæ*, I would return to Royle's original denomination, *i. e.*, *Trizygia.*

From the preceding notes on the genus *Asterophyllites* and *Sphenophyllum*, it would appear that some forms of these two genera may belong to the same plant, but in some other cases *Sphenophyllum* is an independent genus.

In the Indian coal-fields the form *Trizygia*, said to be representative of the carboniferous *Sphenophyllum*, is not associated with any *Asterophyllites*, there being no true *Asterophyllites* found; nor can it belong to *Schizoneura*, which to some extent can be considered as representing the *Asterophyllites;* for amongst the very numerous specimens of *Schizoneura* from the Indian coal-beds, not one specimen was observed which would show that the *Trizygia* might in some way be connected with *Schizoneura;* in the Talchir coal-field there is *Trizygia* without *Schizoneura*, and in the European Trias, where *Schizoneura* occurs, no trace of any form of the kind of *Trizygia*, or any *Sphenophyllum*, has hitherto been detected. *Trizygia* can therefore very well be considered an independent genus, having no connection with *Schizoneura*, as those forms of *Sphenophyllum* which have no connection with *Asterophyllites;* but I also think *Trizygia* will have to be considered as differing from the true *Sphenophyllum.*

In this latter the leaves are arranged in complete whorls round the joints, and the stalk is pretty thick, so that we have to consider it as an erect plant, growing

[1] Flore carbonifère du Dptmt. de la Loire et du Centre de la France, 1877.

above the surface of water, like *Asterophyllites.* In the Indian plant, however, the leaf whorls are incomplete, there being always only six leaves, on one side of the joint, arranged in three pairs; the stalks are thin in comparison with the size of the leaves, showing perhaps that the *Trizygia* was a plant which floated on the surface of water.

In my paper on some fossil plants from Raniganj,[1] although placing the Indian form with *Sphenophyllum,* I pointed out all these differences, and distinguished two groups of *Sphenophyllum.*

At present I would formulate my view in the following manner :—

EQUISETACEÆ.

CALAMARIEÆ.

Group: *Sphenophylloideæ.*

a.—Leaf whorls complete round the joint; number of leaves variable; leaves of the same size and shape in the same whorl.

The true carboniferous *Sphenophyllum.*

b.—Whorls incomplete on one side of the joints; number of leaves six, arranged in three pairs, of which each differs from the other in size and partly also in shape of the leaves.

The *Trizygia* of the Indian coal-beds.

In this sense *Trizygia* may be considered as representative of the carboniferous *Sphenophyllum,* but is an independent genus.

We have therefore—

Phyllotheca, representing in the fossil flora the living *Equisetum.*

Schizoneura, representing perhaps the genus *Asterophyllites* of the palæozoic formation.

Trizygia, representing the genus *Sphenophyllum,* although differing from it.

ON MYSORIN AND ATACAMITE FROM THE NELLORE DISTRICT, *by* F. R. MALLET, F. G. S., *Geological Survey of India.*

Mysorin.—The occurrence of copper in the District of Nellore, as well as in other adjacent parts of the country, appears to have been first brought to the notice of Government by Dr. Benjamin Heyne in the early part of the present century. In his "Tracts on India," published in 1814, an account is given of the rocks in the metalliferous region, and some details as to the nature of the ore. But the working of the mines, which appears to have been carried on extensively at an earlier period, was in abeyance at the time of Dr. Heyne's explorations, so that he was unable to obtain any reliable information as to the mode of occurrence of the ore, or its quantity. He was led, however, to suppose that the amount

[1] Jour. As. Soc., Bengal, 1876, p. 342.

was very considerable, and that the working of the mines "had not been given up for want of ore, but from the jealousy of the Rajahs, who wished to hide such a treasure as long as possible from their superiors." Specimens of copper ore were obtained by Dr. Heyne, from near the surface, in several localities. Most of it was "malachite and mountain green," but there was also a dark-colored ore, intimately associated with the above, a sample of which was sent to London, and analysed by Dr. Thomas Thomson. His results were published in the Philosophical Transactions for 1814, and were reprinted as an appendix to Dr. Heyne's work above referred to. Dr. Thomson described the ore as follows:—
"All the specimens of this ore which I have seen are amorphous; so that, as far as is known at present, it never occurs crystallized. Quartz crystals indeed are imbedded in it abundantly and very irregularly. Sometimes they are single, sometimes they constitute the lining of small cavities to be found in it. These crystals are all translucent. In some rare cases they are colorless; but by far the greater number of them are tinged of a yellowish-red, and some few of them are green. The mineral is likewise interspersed with small specks of malachite; and with dark, brownish-red, soft particles, which I found to consist of red oxide of iron.

"The color varies in consequence of the irregular distribution of these extraneous substances. One specimen, which was the most free from the malachite and the red particles, was of a dark blackish-brown color. But in general the color is a mixture of green, red, and brown; sometimes one and sometimes another prevailing. Small green veins of malachite likewise traverse it in different directions.

"The fracture is small conchoidal, and in some parts of the mineral there is a tendency to a foliated fracture. The lustre is glimmering, owing, I conceive, to the minute quartz crystals scattered through it. The kind of lustre is resinous; and on that account and the varieties of colors, this ore has a good deal of the aspect of serpentine.

"It is soft, being easily scratched by the knife.[1] It is sectile. The streak reddish-brown. The specific gravity 2·620.

"It effervesces in acids and dissolves, letting fall a red powder. The solution is green or blue, according to the acid, indicating that it consists chiefly of copper."

The result of Dr. Thomson's analysis was as follows:—

Carbonic acid	16·70
Peroxide of copper	60·75
Peroxide of iron	19·50
Silica	2·10
Loss	·95
	100·00

The oxide of iron and silica he regarded as mechanically mixed, and he therefore considered the ore to be an anhydrous carbonate of copper, and a new

[1] The hardness is given as 4·25 in Dr. Thomson's Mineralogy of 1836.

mineral species. It is described (in an abridged form from the abovementioned paper) in his Outlines of Mineralogy (7th edition, 1836) as anhydrous dicarbonate of copper. In most works on mineralogy, of a date subsequent to Dr. Thomson's, the ore is alluded to as a doubtful species under the name of mysorin.[1]

With reference to the locality in which the mysorin was found, Dr. Heyne wrote: "Malachite and mountain green probably constitute the great mass of the ore in the copper veins, but an immense nest of the anhydrous carbonate of copper was found at Ganypittah, a village belonging to a Jaghierdor in the Venkatygherry district, about 40 miles west of Ongole. It exists there in a rock of the nature of gneiss, but considerably disintegrated, and the quantity of it must be immense, as forty coolies' loads were procured by a little digging, and sent to Mr. Travers, the Collector of the district, and almost as much remained which had been dug out, but which was not carried away."[2]

The village of Ganypittah—spelt Guramanypenta by Dr. Heyne in a pamphlet subsequently published by him, Gurumanipenta by Lieutenant Newbold, and Gunnypentah on the Atlas sheet—is 48 miles south-west of Ongole. From the bearings of the village from Nellore and Cuddapah given by Dr. Heyne, as well as from allusions to other villages in the vicinity, it is perfectly clear that *west* was a mere slip of the pen on his part.[3]

Amongst the specimens which were forwarded to the Geological Museum in 1873, for incorporation in the series illustrating the mineral resources of India, which was sent to the Vienna exhibition, was a parcel of perhaps a hundredweight, or more, of copper ore from "Gudisa Gundla near Ganmanipenta and Yerripali, Nellore District." Yerripali is a village about four miles from Ganmanipenta. A portion of the ore was reserved for the Geological Museum,

[1] From Mysore. The country, however, in which it was found, lies considerably to the east of the Mysore territory of the present day.

[2] In the fourth volume of the Journal of the Asiatic Society of Bengal (1835), there is a paper by Mr. James Prinsep, giving the results of his analyses of three samples of copper ore from the Nellore District. The analysis of one of these, which Mr. Prinsep thought might be the same ore as that examined by Dr. Thomson, is as follows:—

Hydrated carbonate of copper	68·5
Sulphuret of copper	0·?
Sulphuret of iron	12·4
Oxide of iron, silex, &c.	25·1
	106·0

It is, however, alluded to by Mr. Prinsep himself as an imperfect analysis. The third ore examined was sulphide of copper (63·0 per cent.) mixed with hydrated carbonate (31·7 per cent.) and some oxide of iron and silex. In the same paper there is an extract from a pamphlet, published by Dr. Heyne subsequent to the issue of his 'Tracts on India,' in which he describes the appearance of an ore which he considered to be of the same kind as that previously forwarded to Dr. Thomson, but as it seems clear that Mr. Prinsep was right in believing that Dr. Heyne had mistaken the sulphide with carbonate for the mysorin, it is unnecessary to quote the description.

The copper-bearing localities of Nellore and the neighbouring country have been further described by Lieutenant Newbold in volume VII of the Journal of the Royal Asiatic Society.

[3] Journ. As. Soc. Bengal, Vol. IV, p. 575.

and while arranging the copper ores in the economic collection some time ago, I was struck with the outward resemblance of part of the Nellore ore to the Mysorin as described by Dr. Thomson. It is, however, only recently that I have had the opportunity of making a complete examination of it.

The ore, as sent, occurs in irregular broken pieces of various sizes up to about three inches diameter. It is a most heterogeneous mixture, made up of over half a dozen different minerals, some of which are, however, much more abundant than others. Taken roughly in the order of their relative abundance, there are visible to the naked eye, or with a lens :—

The dark reddish-brown ore in question.
Malachite.
Chrysocolla.
Quartz.
Yellowish-brown ochre.
Chalcocite.
Calcite.
Bornite.[1]

Pieces of pure malachite are not to be found, the mineral being greatly mixed up with chrysocolla and other minerals. Some portions of it, owing to dissemminated reddish-brown specks, and specks of chalcocite, have a dark tinge. The chrysocolla, which is green and greenish-blue in colour, occurs both mixed with the malachite, &c., and in the form of thin seams, and as the linings of small cavities. The quartz is crystalline and generally colorless or nearly so, but it appears to have a green or yellowish colour from being imbedded in malachite or chrysocolla or ochre, or from having such running through it in thin seams. The proportion of chalcocite is quite small, but occasionally a tolerably pure mass an eighth of an inch long, or more, may be observed, and it can be seen scattered through many pieces of the ore with the aid of a lens. Calcite is a rare mineral only observed on a few specimens in the form of very thin seams. Bornite is extremely uncommon: only a very few specks have been detected. Some pieces of the ore consist mainly of malachite and chrysocolla, others mainly of the dark-coloured ore.

The most homogeneous portions of the latter have to the naked eye a dark reddish-brown colour, but viewed with a lens they are seen to be finely mottled in dark brownish-red and green. A thin section, which to the naked eye has a reddish-brown colour by reflected light, when viewed with a lens by transmitted light, shows this mottled structure still more plainly. The relative proportion of the two colours varies greatly. Occasionally a patch is found in which the green is almost absent. It is but rarely that one finds a surface of a quarter of an inch square that is not intersected by thin green seams of malachite and chrysocolla, which traverse the ore in different directions. Specks of chalcocite are also visible, and, very occasionally, those of bornite. The ore contains a few small cavities, partially filled with red ochreous oxide of iron.

[1] Besides these there are visible in a few specimens, which include some of the gangue-stone, hornblende, garnet, mica, &c., the matrix of the ore being, according to Lieutenant Newbold, mica- and hornblende-schist.

The lustre may be described as dull to the naked eye, but glimmering under the lens. Fracture imperfect conchoidal. On scratching the ore with a knife the streak is seen to vary in colour owing to the mottled character of the substance. Generally it is greenish and brownish-yellow. In the patches which are free from green it is brownish-red. The fragments which I selected for analysis yielded a buffish-gray powder. Hardness of the ore about 4·0. Specific gravity 3·80 . It effervesces with cold dilute acid, yielding a green or blue solution and leaving a red powder undissolved. On heating this powder with strong hydrochloric acid, ferric oxide is dissolved, and a white powder remains.

On comparing the description Dr. Thomson has recorded of the ore analysed by him with that just given of the ore I have examined, and recollecting that Dr. Heyne has stated that the mysorin occurs in an immense nest at Gannypentah, and that the ore examined by me was sent as the ordinary ore of the same locality, I do not think there is much room for doubt as to Dr. Thomson's ore and mine being the same. The only discrepancy of importance so far is in the specific gravity. Dr. Thomson found it to be 2·62, I 3·80. It may be observed on this point that it seems remarkable that while malachite has a specific gravity of 3·7—4·0, the corresponding anhydrous carbonate should have as low a specific gravity as 2·62. The low specific gravity can scarcely be ascribed to impurity, as Dr. Thomson's analysis shows this to consist almost entirely of ferric oxide.

In the crucial point however—the presence or absence of water—my analysis differs fundamentally from Dr. Thomson's. The fragments selected for analysis showed under the lens the brownish-red and green mottling alluded to above. Minute veins of malachite and chrysocolla were also visible, as well as specks of chalcocite, it being found impossible to obtain a sufficiency of the substance free from such admixture. Minute quantities of barite and probably calcite were also present, although they were not detected by the eye. The result of my analysis of the ore (dried at 100° C.) was as follows :—

Copper equiv. to ·56 of S.	2·22
Copper calculated as cupric oxide	61·46
Ferric oxide (with tr. of Al_2O_3)	6·74
Lime	·26
Baryta	·55
Carbonic acid	15·18
Silicic acid	4·39
Phosphoric acid	tr.
Sulphuric acid	·29
Sulphur	·56
Water [1]	9·02
	100·67

The barium sulphate was included in the residue insoluble in aqua regia,[2] together with the bulk of the silica, which was entirely soluble in alkali. The sulphur was clearly derived from the chalcocite. The ferric oxide was evidently

[1] The amount of water was determined by direct weighment.

[2] Also in the residue insoluble in hydrochloric acid.

mechanically mixed, being left (with silica, &c.) as a red powder when the mineral was treated with dilute acid.

It was not found possible to isolate sufficient chrysocolla in a pure state from the ore to make a separate analysis of it. Adopting, however, the normal composition of the mineral, the above figures would be equivalent to—

		Cu.	CuO.	Fe_2O_3	CaO.	BaO.	CO_2	SiO_2	SO_3	S.	H_2O.
Malachite ...	77·02	...	55·65	...	...	...	14·98	...	...	...	6·39
Calcite ...	·46	...	...	...	·26	...	·20	...	...	...	...
Chrysocolla ...	12·83	...	5·81	...	...	...	...	4·39	...	...	2·63
Barite ...	·84	...	...	...	...	·55	...	...	·29	...	...
Chalcocite ...	2·78	2·22	...	...	...	...	...	...	...	·56	...
Ferric oxide ...	6·74	...	...	6·74	...	...	...	...	...	...	...
	100·67	2·22	61·46	6·74	·26	·55	15·18	4·39	·29	·56	9·02

After deducting the cupric oxide and water equivalent to the silica, and the carbonic acid equivalent to the lime, there remains a residue of, water 6·39, carbonic acid 14·98, cupric oxide 55·65; quantities which have the oxygen ratio of 1: 1·92: 1·97; the oxygen ratio in typical malachite being 1: 2: 2. It is clear, therefore, that the ore is an impure malachite owing its dark colour to admixture with ferric oxide and chalcocite. Some specimens, indeed, of the Gannypentah ore, which are seen to be impure malachite by the eye, have a dark colour owing to a smaller admixture of the same kind.

It is not certain that the lime exists as calcite, but it is probable, calcite having, as before remarked, been found in some specimens of the ore. The point is, however, of no importance with reference to the main question. Thus, if the lime be included with the chrysocolla, the above-mentioned ratio will be 1: 1·94: 1·99.

I have alluded to small portions of the mysorin in which, when viewed with a lens, green is almost absent. Fragments of such, when dropped into dilute acid, give merely a minute bubble or two of carbonic acid; the liquid is faintly tinged with green, and the fragment remains almost unacted on. When heated with strong hydrochloric acid, iron is abundantly dissolved. Such portions of the ore are in fact merely ochreous ferric oxide. The amount of effervescence increases with the amount of green visible in the specimens experimented on.

Atacamite.—Amongst the specimens of copper ore from the Nellore district in the Museum, there is a mass of chalcocite, which appears to have been originally obtained by Mr. Kerr, a gentleman who endeavoured, but unsuccessfully, to work the mines about the year 1835. The specimen weighs about six pounds, and evidently formed a portion of an irregular vein, two or three inches thick. It contains a few disseminated crystals of magnetite, and is intersected by small,

irregular seams containing (with some malachite) dark emerald green, translucent, crystals, which, on examination, proved to be atacamite. The point is worth notice, in that the locality in question is, I believe, the only one in which atacamite is known to occur in India.

ON CORUNDUM FROM THE KHÁSI HILLS, BY F. R. MALLET, F. G. S., *Geological Survey of India.*

Amongst the specimens lately transferred from the Economic to the Geological Museum, was one of "hone stone", locally known as "maushynrut", from the Khási Hills. Its high specific gravity attracted my attention, and on examination it proved to be corundum. It is a finely granular, light gray, or grayish-white rock, containing microscopically minute specks of a translucent, dark red, mineral. It scratches topaz with ease. The specific gravity is 3·93. It appears from information obtained by Colonel Sherer, Deputy Commissioner of the Khási and Jaintia Hills, to whom the matter was referred, that the mineral is procured at a village called Nongryniew "towards the north-west of, and at a distance of about two days' jonrney from Nongstoin." Nongstoin is the capital of a petty Khási state; latitude 25° 31′ longitude 91° 20′. It would seem that there are no quarries of the stone, but that the villagers pick up pieces found loose on the surface, and use it locally, as before mentioned, for hone or rather grind-stones.

As the edge of the hills to the north-west of Nongstoin is about 30 miles from that place, and within 15 miles of the Brahmaputra, it would appear that the locality where the corundum is found cannot be very far from the edge of the hills, and that it is within a day or two's journey from the river, for carts or laden animals. If, therefore, the stone occurs in large quantity—a point respecting which no information is available—it is worth attention commercially. Corundum is found in large quantity in South Rewah,[1] and notwithstanding the fact that it is more than a hundred miles from the railway, over a road of which the first third is execrable even for laden cattle, and impassable for carts, the corundum is exported to some extent to Mirzapur. The Khási stone, therefore, if found near the edge of the plains, would be far more advantageously situated with respect to carriage. The Rewah corundum is a tougher, less easily pulverized stone than the Khási. Whether the powder of the latter, however, would do the same amount of work as that of the Rewah, is open, perhaps, to question. We are indebted to Colonel Sherer for a specimen of the corundum lately received, weighing about 20 pounds and measuring about 4 × 7 × 9 inches. It had evidently been in use as a grindstone.

[1] Records, Vol. V, 20, Vol. VI, 43.

NOTE ON THE JOGA NEIGHBOURHOOD AND OLD MINES ON THE NERBUDDA, *by* G. J. NICHOLLS, C. S., *Officiating Commissioner of Excise, Central Provinces.*

In the tract of country between the Great Indian Peninsula Railway, the Chota Táwa (which divides the Nimár and Hoshangabád districts), the Nerbudda and the Ganjál river, most of the western area is composed of metamorphics and Bijáwars, and these in the eastern area pass under alluvium.

Granitic and syenitic rocks show at Harda in the river bed. These rapidly pass into gneiss as we go north-west towards Handia. The gneiss soon passes under cherty bands and quartzose breccia. Due north from Harda about seven miles, and to the east of the road to Handia, the streams lay open beds of much disintegrated granitoid or gneissic rock which would probably yield kaolin.

Between two and three miles south of Handia small hills, with a westerly run, are met, composed of a peculiar quartzite belonging to the Bijáwar series.

At Handia the bed of the Nerbudda is of granite, the felspar being of a marked red colour. Across the river at Nimáwar, the quartzites again come in.

From Harda to the south-west, granites are found till the Máchak valley is met near Mandla. Further down the railway line trap comes in, a softish red or reddish purple stone, easily cut and used for bridge work.

Down the Máchak which runs in a north-west direction at Dhanwára, a coarsely crystallized protogene rock forms the bed of the stream.

At Deopur a limestone has been quarried to a considerable extent.[1]

Westward of this, through Gambir to the Chota Táwa, there is much schist and gneiss, with trap outliers superimposed. Going due west of Harda to Sontalai, I quickly left the granite and syenite and passed beyond the gneiss. From this to Sontalai, bands of yellowish brown chert and outcrops of a highly silicious limestone (Bijáwar) alternate in a most confused manner. Where there are hills, as at Niljhar, they are mostly of quartzite with chert and jasper. The surface of the limestone is much weathered and gnarled, and the silicious layers stand out in relief, often assuming the half vitrified look of hornstone. Close to Sontalai, there is much ferruginous debris, probably from the numerous iron melting furnaces once worked on the western side of the village.

A curious conglomerate rather than breccia occurs in the stream west of the village. In the afternoon I went to the iron mine about two and a half miles from Sontalai near the Máchak river, seemingly a pocket of hæmatite and iron ochre it has been worked out to a depth which is below the present level of the water in the pit. About here, frequent and quick transitions take place from gneiss to schist and narrow greenstone or diorite bands, giving the appearance of inter-stratification. The position of these and of the schists is generally nearly vertical. Lumps of quartz and nodules of trap lie about on the ground, also a few agates and flints. From Sontalai to Joga across the Anjan, the trap and greenstone dykes, and metamorphic schists disappear. The elevations are almost entirely of quartzite, and the yellow-brown cherty jasper is much stronger. South of

[1] The specimens forwarded are of Lameta limestone, the same as that quarried at Jabalpur.

H. B. M.

Joga Khurd, a strong course of Bijáwar grey weathered limestone strikes to cross the Nerbudda, which river here runs from north to south. The limestone course can be seen forming a reef across the bed of the Nerbudda, but not quite at right angles. The course is nearly north-east-by-east to south-west-by-west.

Between Joga Khurd and Joga Kalán, cherty or jasper breccia is very common, and almost seems to overlie the Bijáwar limestone. From Joga Khurd it is about half a mile to the excavations known all through the country as the "Chándi Khadán" (silver mine).[1]

The pits are in two parallel lines. The most northern line is apparently a continuous excavation of about half a mile in length on the Bijáwar limestone band. The depth and width vary greatly, and the direction runs pretty straight. These open excavations end about 250 yards from the banks of the Nerbudda; the line, I think, generally showed some elevation as compared with the ground on either side. The depth may be generally about 25 feet, and the breadth 15 feet. About 250 yards south of this line of excavation is the second line of excavations; these are generally much narrower and much deeper, much more like evidences of sinking on a lode. Here generally there was a determined dip of about 80° to the north, the strike being as described where the limestone reefs cross the Nerbudda. Where the limestone ridge comes to the surface, the weathered appearance of the rock is remarkably wild and weird. The excavations are not all in one line or continuous. Apparently parallel and intersecting lodes or leaders have been followed.

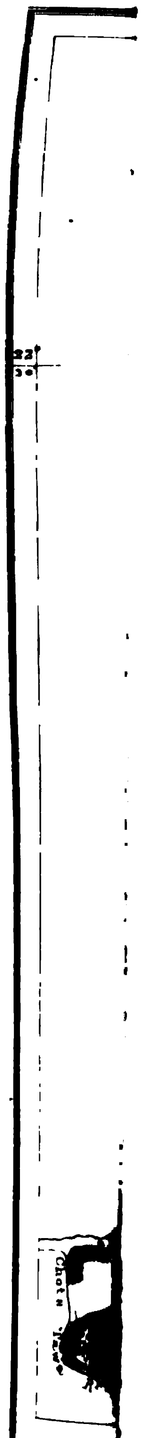
The length of these excavations was less than that of the northern run. In some places from ten to twelve feet in width appear to have been dug out, but generally six feet would be the average. In some parts a considerable depth, about 40 feet, was attained; only in one pit is water found. This has a depth of 8 feet in a small pit or pocket at the extremity of the excavation, which elsewhere was about 30 feet deep. From this I took most of my specimens.

Although at the surface the rock is very contorted, and shows some sign of concentric formation and numerous silicious bands like hornstone, we soon get down into fairly settled ground. But at the bottom I saw a tendency to pockets, there being round holes or nests picked out by the old miners. From the depth where I was working, I could see nothing else to lead me to think that the lode went no deeper; but I had not the opportunity of testing this. From the specimens procured it will be seen that the limestone, through which probably a strong lode ran, is interspersed with mineral. This shows most frequently in the

[1] The reputation of the old pits at Joga as silver mines is certainly of no very recent invention. In March 1855 my attention was drawn to them by Captain Nembhard, then Assistant Commissioner at Hoshangabad. I found the mines just as described by Mr. Nicholls (there were then no maps of the ground); the deposit seemed to be so thoroughly worked out that I had some difficulty, with only a hammer, to make out what the ore was. A very much richer ore than any now visible was no doubt found in the old excavations, and it is quite possible that similar bunches may still lie to the deep of the old workings. The Karnpura iron ore, which is probably that referred to by Mr. Nicholls, occurs as a vein in the Bijáwar jasper-breccia. It is a rich red-hæmatite, though in places much mixed up with the jasper rock.

H. B. MEDLICOTT.

Nichols



On stone by

lines of jointing. It would look as if occasionally I have got fragments of leaders or strings belonging to a large lode. I saw no marks of blasting, or of the use of crowbars.

The country around is all forest, and the soil very poor. The Mowassi Kurku is almost the only inhabitant. He is superstitious and would never have been able to execute the mining work to be seen at Joga. This was probably done by the Patháns, who held the fortress at Joga Kalán, a building supposed to be of the time of Alamgir. Many other reasons besides exhaustion may have led to the abandonment of these works: for instance, inability to control the water in the lower levels, want of acquaintance with machinery for raising the ore with tools, and methods of blasting for breaking down the rock, or the fall of the Mogul power at Handia, and the succession of the Mowassi and Pindhári robber hordes. One cobra put to flight five workmen of mine. They considered him to be the guardian of the treasures. In prospecting both this year and last, I had to use my rifle.

Possibly it might be worth while to spend a little money in trying to expose the lode or in driving cross-cuts. Water power is probably available for stamping.

NOTE.

The samples from the Joga mines, sent by Mr. Nicholls to the Geological Survey Office, were as follows :—

No. 1.—Dug by Mr. Nicholls from the remnant of the *gangul*, or pocket, near the bottom of the 'water pit'—gray dolomitic limestone, containing a few cherty layers : galena is very sparsely dissemminated through both limestone and chert, and in one or two specimens, specks of copper pyrites were observed.

No. 2.—Dug out from side of the excavation of the 'cobra pit'—specimens similar to No. 1.

No. 3.—Casing of a pocket in the 'water pit', dug out by Mr. Nicholls—ferruginous, manganiferous, dolomitic limestone with cherty bands; galena and copper pyrites dissemminated as in No. 1.

No. 4.—From debris at surface of 'panther pit,'—gray dolomitic limestone with specks of galena.

No 5.—Casing from 'water pit,' dug out by Mr. Nicholls—ferruginous, manganiferous, dolomitic limestone.

No. 6.—From debris of 'water pit' and 'hyæna pit'—same as No. 5. Some pieces are sufficiently ferruginous to be called spathic iron. Contains a few specks of galena.

Besides the above, a quantity, perhaps half a cwt., of stone was sent, taken from the debris of several workings. It was similar to the sample No. 1.

None of the above described samples showed any signs of the existence of a lode. The galena is very scantily dissemminated through the limestone and chert themselves. The percentage of ore to gangue is extremely small, so much so that it was necessary to pulverize and wash several pounds of stone to obtain sufficient galena for an assay. The specimens sent are themselves useless as an ore, although of course indicating the possibility of galena occurring in larger quantity. As they were mostly taken from the mere debris of the mines, they cannot be regarded as fair samples of what the average ore formerly extracted was. To really test the value of the mines, it would be necessary to excavate sufficiently deep to penetrate beneath the old workings.

The lead extracted from the galena was found to contain 21 ounces of silver to the ton; a very fair proportion, but certainly not one which would entitle the mines to the name of 'silver mines,' rather than lead mines.

F. R. MALLET.

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SEN CARLOS RIBEIRO.

June 30th, 1879.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1879. [November.

NOTE ON THE "ATTOCK SLATES" AND THEIR PROBABLE GEOLOGICAL POSITION, *by* DR. W. WAAGEN.

In the Records of the Geological Survey of India, Vol. XII, pt. 2, there is a paper by Mr. Wynne, entitled "Further notes on the geology of the Upper Punjab," which bears a special interest on account of the general views on the geology of that country. As many of the points treated of in the paper are yet to be considered as open questions, it seems not advisable to pronounce any opinion on them until further materials have been collected, but it may not be useless to notice some points which might be of value towards the elucidation of the questions discussed by Mr. Wynne.

There is before all the age of the "Attock slates." Mr. Wynne is quite right when he considers the evidence upon which the opinion of their being of silurian age is founded very scanty indeed; and only the absence of any other clue towards the determination of the age of those slates could at the time justify the opinion expressed in our joint memoir on Mount Sirban, that the occurrence of lower silurian fossils in gravels in the Kabul river, which lay approximately in the strike of the "Attock slates," would make a silurian age probable also for the latter.

It is very much to be regretted that to the careful search of Mr. Wynne the slates have proved absolutely unfossiliferous up to the present. Yet this sterility in fossils seems not to prevail at all localities. Among the materials which have been most liberally sent to me by the Geological Society of London, there are about a dozen specimens of a Spirifer, which bear, however, only the label "Punjab." These specimens are preserved in a black slate, which, if the specimens came really from the Punjab,—and there is no reason why this should be doubted,—must have belonged to the Attock slates, as there is no other rock known to me in that part of India which would bear similar petrographical characters, and from which the specimens could have come.

Though these fossils are more or less deformed by oblique pressure, yet the species can without difficulty be determined. All the specimens belong to one and the same species, and cannot be distinguished from *Spirifer keilhavi*, Buch., (*Sp. Rajah*, Salt.). As this species is one of those most characteristic of the carboniferous formation in the Himalaya, and as thus the determination of the age of the rocks from which these fossils came considerably differs from the age hitherto attributed to the Attock slates, it is necessary to be doubly cautious in accepting the current opinion regarding these slates.

The rock in which the fossils are preserved is, as stated above, a black, not very hard slate, such as I have seen to occur at many places in the Attock slates; but there are also outside of the Punjab some localities where similar slates occur. I have myself seen similar slates from the Milam pass which seem also to belong to the carboniferous formation, and seem to be there inferior to white limestones, also full of carboniferous fossils, the latter, however, of a much more recent type. Similar slates have been described by Lydekker from Eishmakam in Kashmir, whilst at other places in the same territory the carboniferous formation is composed nearly entirely of thick limestones. The slates of Eishmakam have been compared by Lydekker to the "Kiol group" and the limestones to the "Great limestone" of the outer Himalaya. Thus it might be very possible that in the Himalaya the carboniferous formation should present two sub-divisions, one older slaty, and one younger calcareous sub-division. This, however, does not prevent that at many localities the whole formation might be made up of massive limestones.

If, therefore, the fossils under consideration did not come from the Punjab, they might have come from several parts of the Himalaya. There is, however, no reason to doubt their coming from the Punjab. There exists in the Punjab a great amount of rocks perfectly similar in appearance to the rock in which the specimens occur, and if these rocks up to the present have proved apparently unfossiliferous, this does not exclude the possibility that there exist localities where fossils do occur. That all these fossils belong only to one species already goes far to prove that the slates containing them are not very rich in fossils. How much it depends on circumstances whether one does meet with certain fossils is also exemplified by the fact that I as well as Mr. Wynne have been searching in vain in the Salt-range for determinable plant remains, and yet there are several beautifully preserved plant remains from the Salt-range in the Geological Society's collection.

Thus we may fairly accept the indications of the label attached to these specimens of *Spirif. keilhavi* as correct; and from this it would follow, that the Attock slates will have to be considered in future as belonging very likely to the carboniferous period.

If we accept this view, one of Mr. Wynne's remarks becomes of special importance; this is that the limestones of Gandgarh remind one more or less of the great limestone of the Jamu hills. This would fit entirely into the state of things observed elsewhere, and the discrepancy, at least in the carboniferous formation, between Kashmir, Jamu, and Hazara would no longer be so striking as is supposed by Mr. Wynne. These limestones are entirely absent in the

neighbourhood of Mount Sirban, and this absence possibly might account for the marked unconformity there between the Attock slates and the more recent formations.

But also for these latter the determination of the Attock slates as of carboniferous age would have a deciding influence, as then the geological horizon they occupy might approximately be fixed. In the little memoir on Mount Sirban, Mr. Wynne and I have distinguished a group of rocks as "Below the Trias," consisting chiefly of cherty dolomite, to which are subordinate red sandstones and quartzites. We have separated these rocks from the Trias for the simple reason that there existed no proof of any kind that they belonged to that formation, and as we then considered the Attock slates as of silurian age, the number of formations to which those strata "Below the Trias" could have been assigned, was so very large, that it seemed only prudent not to express any definite opinion as to their age. Now the case is quite different: these beds would rest unconformably on the carboniferous Attock slates, and be succeeded conformably by upper triassic or rhætic strata; thus it becomes very probable that the strata "Below the Trias" represent the Lower Trias, *viz*., Muschelkalk and Buntsandstein formations.

In his more recent memoirs Mr. Wynne introduces the designation of "Infra-triassic group" for these strata, and most recently he considers this group as identical with his "Tanol series," which is extensively developed in the northern part of Hazara; but such a homotaxis can hardly be maintained. Wynne's "Infra-triassic group," or the group "Below the Trias" of our joint memoir on Mount Sirban, consists chiefly of cherty dolomites, and exhibits sandstones and quartzites in a subordinate manner only, whilst according to the sections published by Mr. Wynne, the Tanol series consists chiefly of slates, sandstones, and quartzites, to which the dolomitic limestones are subordinate.

Besides this the thickness of the group "Below the Trias" and that of the Tanols is so enormously different that a comparison between the two is barely possible.

The only formation to which the Tanol series seems to bear some resemblance is the silurian of the more central parts of the Himalaya (Milam pass, Niti pass), where the fossiliferous beds consist also of white sandstones.

The apparent superposition of these Tanol rocks over the carboniferous Attock slates can be no reason for the rejection of such a parallelisation. Before it is possible to accept Wynne's view that the Tanols are more recent than the Attock slates, and pass upwards into the gneiss which composes the central Himalayan chains, much stronger proofs, stratigraphical as well as palæontological, than those published in his memoir must be adduced; and until decisive materials are available, it will be much more prudent to consider the whole silurian Tanol series as overthrown and faulted against the Attock slates. Then the riddles of the geology of Hazara will easily be solved.

ON A MARGINAL BONE OF AN UNDESCRIBED TORTOISE, FROM THE UPPER SIWALIKS, NEAR NILA, IN THE POTWAR, PUNJAB, *by* W. THEOBALD, *Geological Survey of India.*

The bone which forms the subject of the present remarks, and of which a figure of the natural size is given, is remarkable for exhibiting a structural adaptation which exists in no living species, and, so far as I am aware, has not yet been described in any fossil. It will be necessary, therefore, to refer it to a new genus which I propose to associate with the name of the illustrious fellow-worker of Falconer, Colonel Cautley, and characterize as follows :—

CAUTLEYA.

Genus *Emydinorum*, novum, in quo sternum, et thorax, et ossa marginalia, suturâ tripartitâ cartilagineâ junguntur, sectionem morsum hirudinis simulantem monstrante.

The above character suffices to demonstrate the distinctness of the species under consideration from any previously described, and the specific designation is derived from the most prominent character of the animal as yet known, and in the annular arrangement of the marginal bones.

C. ANNULIGER, n. s.

The marginal bone, whereon I base the above genus and species (and which, except a slight fracture at one corner, is perfect), is trapezoidal in shape and cuneiform in section. It presents an upper and under surface, respectively slightly concave and convex, which were shown to have been external surfaces by the clearly marked furrow which traverses them, and indicates the junction of the superficial or dermal scutes (fig. 1, *a b*, fig. 2, *c d*). The bone is bounded laterally by a jagged sutural surface, whereby a complete and rigid bony union was effected between it and the adjoining marginals, which must have constituted an encircling bony ring of an extremely rigid character, from the great horizontal breadth of the bones in question. The peculiar and characteristic feature, however, of the bone lies in its internal margin (fig. 3, *e f g*) which displays a smooth surface, indicating a cartilaginous union only, with the bones of the sternum and thorax. This inner marginal surface is obscurely divided into two areas of unequal breadth, of which the lower is broader and opposed to the sternal plate, whilst the upper and narrower surface receives the thrust of the bones of the thorax. The thorax and sternum were no doubt united by a cartilaginous suture, as a cartilaginous junction with the marginal is opposed to the idea of a rigid bony union between the bones in immediate contact with them, since a rigidly anchylosed bony ring united only by cartilage to bones themselves joined by a bony suture, could lend no additional strength, though it undoubtedly would do so supposing it to cover and defend a cartilaginous union of the sternal and thoracal bones.

The length of the external margin is 5·5 inches, which indicates approximately an animal close on 10 feet in circumference. The condition of the suture shows that the individual was not of full age, and 12 or 14 feet may probably be assumed

Theobald: On a marginal bone of an undescribed tortoise

1

Upper

J. Schaumburg Lith.

as not an over estimate of the dimensions of the fully adult animal, which probably exceeded the dimensions of the largest *Chitra*, though our positive knowledge of the precise limits attained by our living Chelonian is singularly meagre and limited. That *Cautleya* was an aquatic species may be inferred from the cartilaginous union of the bones of its case, which in living species is seen in such fluviatile forms as *Cuora* and *Cyclemys* and is unknown in terrestrial forms. The opposite conclusion, however, among Chelonia cannot be drawn from the complete ossification of the body case, as *Batagur* and its allies are possessed of as completely ossified a case, though strictly aquatic, as *Testudo*, which is entirely terrestrial.

The specimen was obtained near Nila, on the Sohan river, in the Rawalpindi district, in upper Siwalik strata, and in company with remains of *Mastodon perimensis*, F. et C., *M. pandionis*, F., *Palæopithecus sivalensis*, Lyd., *Acerrotherium perimense*, F. et C., and other Siwalik fossils.

Among the collection from the same locality are fragments of a large Testudine, exceeding in size the living *Manouria*. They consist of one anchylosed pair of episternal bones, with a transverse diameter of 8·5 inches (allowing for a slight fracture); a single right episternal bone of a rather larger size, 2·5 inches thick and 6·25 long, and a free marginal (that is, one anchylosed to the thorax only) 3·3 broad and 4·5 long (measuring from the outer margin).

These bones would indicate an animal nearly as large as the last, and probably fully equal to it in bulk. At present, however (with no other materials), it seems undesirable to give it a name.

SKETCH OF THE GEOLOGY OF NORTH ARCOT DISTRICT, *by* R. BRUCE FOOTE, F.G.S., *Geological Survey of India.*

Topography.

The North Arcot District, one of the purely inland districts of the Madras Presidency, is topographically characterized by its great irregularity of surface. Except in its south-eastern quarter, the district is extremely hilly and in some parts quite mountainous. In the west and north-west it embraces a considerable part of the high and rugged eastern scarp of the great Mysore plateau, from which many long spurs jut out far to the eastward. In the south-west it includes the northern end of the Javádi mountains and the Vellore hills. In the north it includes the well known Tripatti mountains, the "sacred hills of Trippetty," and the southern extremity of the Vellakonda (Eastern Ghâts so-called). The north-eastern corner of the district contains the Nagari mountains; and three groups of lower hills, the Sattavedu, Alikur, and Naikenpalem hills, on the extreme eastern border of the district, and a considerable number of detached hills in the gneissic country west of the Madras railway. Some of these latter, as the Maddur (Muddoor), Sholinghur, and Makrs Drúg hills, and others, are of considerable height and extent. In the south-east of the district only two detached hills need be named, those of Wandiwash and Chitpat (Chittapett).

The hydrology of the district is very simple, all the drainage falling into the Bay of Bengal and chiefly by the Pálár river, which, rising on the Mysore plateau, drains the whole southern half and greater part of the centre and west of the district. The north-eastern part feeds the Korteliar and Nagari (Naggery) rivers, and also the Narnavaram and Suvarnamukhi (Soornamookey).

Hydrology.

The geological formations met with in this district may be conveniently classified into six groups, which may be arranged in their true order of superposition as follows :—

Formations.

RECENT AND POST-TERTIARY.	6.	Soils and subaerial deposits.
	5.	Alluvial deposits ; fluviatile.
	4.	Lateritic sands, gravels, and conglomerates.
MESOZOIC ...	3.	Upper Gondwána series, Rajmahal or "plant" beds.
AZOIC ...	2.	Kadapa series.
	1.	Gneissic series, with intrusive trappean and granitic rocks.

The gneissic series, which forms the basement on which rest all the other rocks, occupies by far the larger part of the whole area of the district, and it is only in the north-eastern and eastern parts that younger rocks occur. The gneissic rocks include all the western part of the district, and form the rugged eastern scarp of the Mysore plateau already referred to (p. 187). Eastward of the plateau, are numerous spurs stretching away from it, and eastward of these again are numerous clusters of detached hills, some of considerable size and elevation, and remarkable for their bold forms and great ruggedness. These occupy the gneiss area up to the very convenient geographical line formed by the north-west line of the Madras railway, eastward of which the gneissic rocks soon disappear under newer formations, to be referred to separately further on. The gneissic area south of the Pálár shows the northern end of the Javádi mountains and the hills east and south-east of Vellore. Further to the south-east the gneiss area becomes comparatively flat, and no hills of any importance rise from its surface, the two hills of Wandiwash and Chitpat (Chittapett) excepted, which have already been named.

General distribution of the rocks.

Gneissic series.

Returning to the north of the Pálár, the gneissic rocks are overlaid by great masses of quartzite and conglomerate belonging to the Kadapa series, which form the greater part of the detached mountains collectively known as the Nagari mountains. The south end of the Vellakonda and the sacred hills of Tripatti to the north are also formed of rocks belonging to the same sub-division of the Kadapa series.

Kadapa series.

The tremendous lines of scarp and often vertical cliffs surrounding in many parts the Nagari and Tripatti mountains give a peculiar and grand character to the local landscape.

South-eastward of the Nagari mountains lie the three hill groups before mentioned (p. 187), *viz.*, the Sattavedu, Alikur (Allcoor), and Naikenpalem hills, consisting of great beds of hard conglomerates and sandstones in the Sattavedu and the eastern half of the Alikur hills, and of uncompacted conglomerates, clays and shales in the western half of

Upper Gondwána rocks.

the Alikur hills and the Naikenpalem group. Some of these beds are fossiliferous, and the fossils show them to belong to the upper division of the great Gondwána system, which includes all the plant-bearing beds in the peninsular area. The fossils agree in many cases, specially with those found in the Rajmahal beds of Bengal.

South of the Naikenpalem hills are other outcrops of the "plant beds" lying between the Nagari river and the Kortelliar. South of these again and south also of the Pálár, the Upper Gondwánas re-appear in a considerable number of small patches dotted over the surface of the eastern part of the gneissic area in the Arcot taluq.

Lateritic rocks.

Much of the surface of the "plant beds" is masked by lateritic deposits, which overlap also in many places on to the gneiss. They do not cover much ground in North Arcot. One of the uppermost places in the superposition of the rocks, but the lowest in point of elevation over the sea level, is occupied by the alluvial formations, which are all fluviatile. Although of very limited extent, they yet offer some points of considerable interest.

Alluvial formations.

The soils are of no special interest, but among the subaerial deposits, the enormous masses of talus which surround the mountains in the north-eastern part of the district are remarkable.

Previous observers.

But very little had been written on the geology of North Arcot before it was taken up systematically by the officers of the Geological Survey Department. Dr. Buchanan and Dr. Benza had given short notes on the geology of the country along the Madras-Bangalore road between Arcot and the Mysore frontier, and Lieutenant (afterwards Colonel) Baird Smith, of the Engineers, had published a paper "on the crystalline structure of the trap dykes in sienite of Amboor," entering elaborately into the questions connected with the formation of such rocks.

The Geological Survey.

The geological survey of the district was taken up in 1863 and continued in the years 1864 and 1865, the work being undertaken by Mr. C. Æ. Oldham, Mr. W. King, and the author. About two-thirds of the district was surveyed, the greatest part being done by Mr. Oldham, who examined the south-eastern and central parts, while Mr. King surveyed the north-western corner. The eastern part north of the Pálár, and the Vellore and part of the Gudiattam (Goriattum) taluqs in the south-western corner of the district, were surveyed by the author.

The Chittur, Palamaner, part of the Gudiattam taluqs, and the Punganur zemindari, though not surveyed, were traversed in several directions by Mr. C. Æ. Oldham and the author, and sufficient is known of them to form an idea of their general geological features.

Its results how published.

Of the information gained by the geological survey part only has been hitherto published. So much of the eastern part of the district as lies within the eastern half of sheet 78 of the Indian Atlas has been illustrated in a geologically colored copy of that half sheet printed in 1872. The features of the northernmost part of the district, including the Tripatti and Nagari (Naggery) hills, were shown in the small-scale general

map of the region occupied by the Kadapa and Karnul rocks, published with Mr. King's memoir on those rocks in 1872,[1] and the component rocks described in that memoir.

Of the country illustrated in the geological edition of sheet 78 (eastern half), only part has been described in any of the publications of the Geological Survey hitherto issued.

The part described included the south-eastern half of the Wallajah taluq, the eastern part of the Karvet Nagar zemindari, and the south-eastern part of the Calastri zemindari; the description of these was given in a Memoir by the author published in 1873.[2] Brief references to the three tracts just named and to the Nagari region had been published rather earlier by Mr. King and the author in two papers in the Records of the Geological Survey of India, under the respective titles, "On the Kuddapah and Kurnool Formations" (1869), and "Notes on the Geology of the neighbourhood of Madras" (1870). Some of the geological features of the North Arcot country were also referred to in a paper "On the occurrence of stone implements in the formations in various parts of the Madras and North Arcot districts," published in the Madras Journal of Literature and Science for 1866 by the author, with notes by Mr. King. The same and some other geological features of the North Arcot country were touched upon in another paper "On the distribution of stone implements in Southern India," read by the author before the Geological Society of London in 1868 and published in the Society's Journal for the same year.

The Memoir "On the Geology of parts of the Madras and North Arcot districts," &c.,[3] above quoted gave a rather full account of the Upper Gondwána and overlying lateritic rocks in the Arcot district, as also of the alluvial valleys of the Nagari and Narnavaram rivers. The information there given will be repeated in a somewhat condensed form in these pages, together with a good deal of new matter not yet published, owing partly to the non-completion of the survey of the district, but mainly to the premature decease of Mr. Charles Æ. Oldham.

The only geological map on which North Arcot had been represented on an intelligible scale prior to the publication of the geological edition of sheet 78 was Greenough's general geological sketch map of India, published in 1854, a laborious but in many respects untrustworthy compilation. The features of the North Arcot country are laid down very incorrectly in this map, the data from which it was compiled being utterly insufficient for the purpose.

The older rocks of the district being in great measure the source whence the materials for the formation of the newer ones were derived, it will be most convenient to describe the several groups recognized in their ascending order of sequence.

[1] Memoirs Geological Survey of India, Vol. VIII.

[2] Memoirs Geological Survey of India, Vol. X, pt. 1: "On the geology of parts of the Madras and North Arcot districts lying north of the Pálár river and included in sheet 78 of the Indian Atlas."

[3] Memoirs Geological Survey of India, Vol. X, pt. 1.

GROUP I.—*The Metamorphic or Gneissic rocks.*

It has already been pointed out that the rocks belonging to this group occupy by far the greatest part of the whole district. The predominant varieties are the massive obscurely bedded ones known among geologists as granite-gneiss and syenite-gneiss. The well-bedded fine-grained schistose varieties are much less frequently met with than in other parts of the great gneissic region, as in the Trichinopoly, Salem, Madras, and Nellore districts, but they do appear locally among the coarse granitoid varieties, and occurrences of them will be described further on.

As in all the gneissic regions, the rocks show abundant signs of having been much disturbed, contorted and uptilted since their original deposition, and finally forced into series of great synclinal and anticlinal foldings, the edges of which may in some cases be easily traced along great distances.

Prevalent strike.

A study of the direction of the edges or outcrops of the beds, technically called the "strike" of the bedding, shows that in the south-eastern part of the district the beds have a strike from south-south-west to north-north-east, but as they are traced northward they are found to trend till they run north-south, which is the prevailing strike in the central parts of the district. If followed into the extreme northern part, they will be found to have trended to north-north-west. This change in the strike is part of a great curve formed by the metamorphic rocks in the latitude of Madras, and affecting the whole gneissic series eastward of the Mysore plateau.

In describing the general appearance of the central part of the district, Mr. Oldham in his notes remarks very aptly: "Speaking generally. the whole area might be said to be one of quartzo-felspathic gneiss, commonly syenitoid or granitoid." "When, however, I say quartzo-felspathic, I do not mean to imply that these minerals only constitute the rock, but that they preponderate largely, and that the hornblende and mica which also enter into its composition play a very subordinate part, except in occasional bands." These remarks apply equally well to the general features of the rugged flanks of the plateau edge as seen in the Sainegunta and Mugli Ghâts and at Satghur, and to the whole western part of the district in fact. They apply also fully to the gneiss of the eastern side of the district north of the Pálár, but less so to the rocks of the south-eastern taluqs. Here and around Vellore the well bedded varieties are rather more largely developed, and they are much less largely quartzo-felspathic in constitution.

Commencing in the western part of the gneissic area, the eastern edge of the Mysore plateau consists mainly of coarse granitoid gneiss, which is well seen in the hills west of Ambur, at Satghur, and thence generally on the Sainegunta and Mugli Ghâts leading to Palamaner, all around that place and northward of it, very conspicuously in the Gam Kondas and other hills stretching away to Avulpilli Drug. The same description applies to the whole of the country between Vellore and Chittur, and to the very hilly tract lying between the Poiney river and the Madras railway. East of the railway too the granitoid gneiss extends under the younger Kadapa and Gondwána rock series.

In the southern part of the gneissic area, forming the northern end of the

Javádi mountains, are great bands of granitoid gneiss, some of them remarkable for their coarseness of texture, which is blotchy and often markedly porphyritic, *e. g.*, the rock forming the mass of the Palikonda (Policondah) mountain and of the Vániambádi[1] trigonometrical station hill, some three or four miles to the south-south-east. Similar "blotchy" gneiss is of very common occurrence elsewhere. In the Palikonda hill the rock is of a hornblendic variety, and of grey color.

A remarkably handsome variety of porphyritic hornblendic granite gneiss of rich green and pink colors occurs at the western base of the Nagari (Naggery) Nose mountain, and is exposed in several cuttings along the Madras railway (north-west line). Masses and boulders of this variety are to be seen included in large numbers in the basement conglomerate of the Upper Gondwána rocks in the Pyanur area south of the Nagari river.

The contrast between the rich dark-green hornblendic matrix and the large pink or salmon-colored crystals of orthoclase makes the rock a very handsome example of a typical porphyritic granite gneiss.

Quasi "brecciated" gneiss.

A by no means uncommon form of the granite gneiss is one in which the beds include masses of what appears to be an older gneiss, sometimes micaceous, sometimes hornblendic. The included masses present generally sub-angular forms, but others are well rounded, as if they had been boulders, and others again unquestionably angular, so that the mass looks sometimes conglomeratic, sometimes breccioid. In other places again, and often within the same beds and at no great distance, the inclusions have the appearance of having been altered by concretionary segregation. The included masses are mostly of finer grain and of more highly micaceous or hornblendic character than the surrounding masses. There can be little doubt that in some cases the included fragments are really remains of older rocks, and the whole rock a true breccia or conglomerate. In other cases, however, the inclusions are in all probability mere local aggregations of the prevalent or most striking mineral. An example of this latter kind is to be seen in the Chikeli Drug hill, a little to the south-east of Kaneambadi pass, nine miles south of Vellore. Good examples of this quasi-conglomeratic and brecciated structure may be seen to the west of the Nagari railway station, in the low hills close to the railway at Ranawaram near the Sholinghur station, and in the southern part of the district at and to the south of Chitpat (Chittapett), and at Erumbaucum, eight miles to the east-south-east of Arcot, and on the eastern side of the district at Gudinaucarur, six or eight miles east of Wandiwash.

Schistose band of Kailasagiri.

Of the more schistose bands of gneiss, the most noteworthy is the great micaceous band forming the Kailasagiri peak, six miles south-west-by-south of Vellore, which rises in a bold peak to an elevation of 2,677 feet above sea level. This gneiss is compact and massive in structure, and has been uptilted to a very high angle, the true dip of the beds varying from 80° to 85°. The strike of the beds corresponds with the direction of the highest part of the ridge and is north 5° east.

The very coarse garnetiferous micaceous gneiss of Chikeli Drug (already

[1] This place must not be confounded with the town and railway station of the same name on the northern boundary of Salem district.

referred to) extends northward into the Vellore hills, and forms a considerable part of the main ridge of the hill group.

Magnetite beds.

Beds of magnetic iron occur here and there in the south-west corner of the district, *e. g.*, to the south of Gudyátam (Goriattum), half a mile south of the great tank, and again two and a half miles west of Vellore railway station. These beds are small, but interesting, as there can be no doubt that they are representatives of some of the numerous beds occurring south of the Javádi hills in Salem district. Others of these richly ferruginous beds are in all probability represented by various quartzose gneiss beds, very strongly iron-stained, which occur in this quarter. The quartz of these beds is stained of purplish or reddish color, and frequently shows a brown ferruginous incrustation in the cavities between the laminæ, as also numerous little cavities in the lamination which appear once to have been filled by some mineral or other now wanting. These beds have a striking resemblance to the poorly ferruginous parts of many of the typical magnetic iron beds of the Salem region. Good examples of these iron-stained beds are to be seen in the Vellore hills and in the large detached hill three miles south of Vellore.

Quartzo-ferruginous beds.

Probable representatives of the magnetic iron beds are also the numerous quartzo-ferruginous beds noted by Mr. C. Æ. Oldham in the Arcot and Wandiwash taluqs. His notes unfortunately do not mention the form in which the iron occurs. The geographical situation points, however, strongly to these being continuations of the numerous magnetic iron beds occurring to the east and north of the Kabroyen mountains in South Arcot, beds which themselves are unquestionably north-easterly extensions of some of the great magnetite beds of Salem district. Associated with these quartzo-ferruginous beds in the south-eastern part of the district are also numerous beds of hornblendic ferruginous gneiss.

Hornblendic ferruginous beds.

These occur chiefly in the tract of country between Arcot and Wandiwash. To the eastward of this hornblendic band lies a broad zone of highly granitoid quartzo-felspathic gneiss which extends to the boundary of the Chingleput (Madras) district; the great Wandiwash hill belongs to this band.

In the more granitoid region north of the Pálár hornblendic forms are much less common than the quartzo-felspathic forms of gneiss.

Ferruginous beds were noted by Mr. C. Æ. Oldham, chiefly near the Poiney river, *e. g.*, north of Chellempollian; south-west of Bomupilli, eight or ten miles to the north-north-westward; and lastly, to the north of Maimandalum, on the western side of the Poiney river.

Talcose beds.

Talcose beds occur only in a few places. Three were noted by Mr. Oldham, all of small importance. They occur at Damavapak (Damarpauk), north of Arni, a little to the west of the road to Arcot, at a place on the left bank of the Poiney river, eight miles north-north-west of Ranipet cantonment, and lastly, a little to the south-east of Murtapilli and twenty miles north of the last named locality. An extremely quartzose band of gneiss is seen to the north-west of Sholinghur and north of Randareddi (Rundaddy).

In a district where so large an area is occupied by intensely granitoid gneiss, its characteristic features are of course to be seen to great advantage in many places, particularly along the two lines of railway diverging from Arconum junction. Especially characteristic are the hills of Maddur Drug and Trittan on the north-west line, and those of Sholinghur, Nelacontriapetta, and Gudyátam (Goriattum) on the south-west line; all of these show great bare masses of rock with tors, and here and there great precipitous cliffs.

Tors.

Of the tors the two most remarkable groups are both near Nagari; the one, between the railway and the foot of the Nagari mountain close to the northern end of the pass traversed by the old high road to Kadapa; the other, at Neddiem (Neddum) on the north bank of the Nagari river, four miles above the railway bridge. Both groups are of great size and height and form conspicuous objects from considerable distances.

A very common accessory mineral occurring in the granite gneiss is epidote, in its pale apple-green variety known as pistacite; it occurs scattered through the general mass of the rocks, or in minute veins, and very commonly as a thin coating to planes of jointing.

ROCKS INTRUDED INTO THE GNEISSIC SERIES.

The crystalline rocks intruded into the gneissic series are referable to four groups—granite veins, felspathic porphyries, quartz veins, and trap dykes. Of the four groups, the last is by far the most important, and the first the least so, granite veins being very rare and of small size; the trap dykes, on the contrary, extremely numerous, and many of them of large size, and forming important features in the landscape in very many parts of the country.

Granite veins.

The granite veins seen in North Arcot are, with one exception, of quite small size, and all appear to consist of a binary rock, in which only quartz and felspar are recognizable. Some of them contain a few scattered crystals of epidote as an accessory mineral.

Numerous veins of very small size of dark salmon-red color, and highly felspathic in character, occur in the gneiss to the south of the railway station at Vellore, and a larger but still small vein of the same kind occurs at Vajur (Vanjoor), two miles south-west of the railway station.

The most important granitic protrusion noted is a vein occurring at Tarur (Turroor), eight miles east of the great Kaveripak (Covrepauk) tank, and about ten miles south-west of the Arkonum railway junction. It forms a bare and generally smooth ridge one and a quarter mile long, about 40 feet high at its summit. It is a binary quartzo-felspathic granite of coarse grain and full of minute cracks.

The very handsome green and pink syenitoid rock occurring at the western base of the Nagari mountain has been referred to before (p. 192) when treating of the gneissic rocks, but the rock is so extremely crystalline that it might easily be taken for a truly intrusive rock, and the more so as the position it occupies with reference to the surrounding unquestionably gneissic rocks is rather obscure.

The felspathic porphyries occurring in North Arcot district are very interesting, as being the only examples of this species of rock known in the south of the peninsula. Several very fine veins of this porphyry occur south of the Palikonda mountain (p. 192), and two of them may be traced for several miles in an east-to-west direction. In width they vary from 20 to 50 feet, and vary in color from smoky grey to pale drab, when freshly broken. Numerous prisms of flesh-colored or white felspar from $\frac{1}{8}$th to $\frac{1}{2}$ an inch long are included in the felspathic matrix. Small acicular crystals of dark green hornblende are less frequently included. The felspar crystals often stand out in great perfection on the weathered surfaces, and in some parts of the veins the included crystals form nearly half the mass. A little distance south of the western end of these two veins is a third in which the included small dark green acicular hornblende crystals are numerous, but the felspar crystals of rare occurrence in the greyish-white felspathic matrix. The felspar crystals are white and show very faintly.

Felspathic porphyries.

On the east flank of the Palikonda mountain is a drab or pale buff-colored vein which appears to cross the mountain, for a precisely similar rock shows on the west flank. In this case the included crystals consist of felspar and quartz. Two other small veins of the same character appear on the west flank close to the north-west corner of the mountain, and a third of smoky grey color, with reddish felspar crystals, runs nearly east-to-west for two or three hundred yards parallel with the high road to Bangalore on the north side of the mountain.

Another small vein of the felspathic porphyry occurs in the centre of the valley west of Kailasagiri peak (south-south-west of Vellore); it is of the same character as those just described.

In point of age these porphyry veins seem to be newer than the trap dykes they cut in their course. Unfortunately this point could not be definitively settled owing to the presence of soil and debris at the points of intersection.

Quartz veins are not very common. A few were noted by Mr. Oldham in the Wandiwash and Arcot taluqs; they are of good size (two to three miles in length), but offer no special features of interest; their course is either north-east-by-east to south-west-by-west, or north-west-by-north, south-east-by-south.

Quartz veins.

The trappean rocks seen in North Arcot district all occur in the shape of dykes, often of great size and length, and forming important features in the landscape. They occur commonly in all parts of the district, and in the central part occur frequently in very large numbers.

Trap dykes.

The great majority of the dykes consist of coarse hornblendic trap, a form of greenstone, and there is in very many cases a direct proportion between the size of the dyke and the coarseness of the rock composing it. Many of the dykes are markedly porphyritic in structure, including numerous crystals of felspar in a hornblendic or hornblendo-felspathic matrix. If classified according to the directions of their courses, the dykes will be found referable to two great systems, of which the one runs north to south, roughly speaking, and the other east-by-north to west-by-south. In the former, the course is less constant, and varies by

5° or so east or west of north. A relatively small number of dykes does not come under either of these two systems, but they offer no special differences in mineral character, or otherwise to require any detailed notice. There is no marked difference between the trap rock forming the members of the two systems, and they appear to belong to the same geological age. Both agree in being older than the Kadapa system of rocks which they nowhere intrude into. The relations of the dykes at their crossings, are obscure in all cases in this district, but the intersections of other dykes of precisely similar rock and running in corresponding directions in more northerly parts of the gneiss area, *e.g.*, in Bellary district and the Raichur doab, appear to show that the filling up of both sets of fissures by the irruptive material was simultaneous, no difference or change of any kind being observable. Very large and important dykes, such as the great dyke at Sholinghur and some in the Maddur (Muddoor) and Trittani hills, rise to heights of several hundred feet above the surface, and form bold and striking ridges and crests.

Some of the dykes, such as the Sholinghur dyke and the Permalrajapet dyke, some eight miles to the east, are distinctly and strongly magnetic and affect the compass needle greatly. This phenomenon was also noticed in the dyke lying to the west-by-south of the village of Poiney, but not elsewhere.

Excepting a little pale iron pyrites (marcasite) no accessory minerals have been noticed in any of the dykes. The pyrites were seen in some of the dykes traversing the hill east of Vellore town.

Well characterized examples of porphyritic greenstones are to be seen to the south-east of Ranipet cantonment, and in the railway-cutting south of Pudi station on the north-west line of the Madras railway. As a rule, with few or no exceptions, the greenstone weathers more slowly than the surrounding gneissic rock, and consequently the dykes form ridges running over hill and dale, and from their dark color contrasting strongly against the gneiss.

The courses of many of the dykes may be followed for twenty or thirty miles or even more, and the larger ones have a width of from 50 to 100 paces. The network formed by these multitudinous dykes is one of the most remarkable displays of trappean injection known in any country.

THE KADAPA SERIES.

The representatives of the Kadapa series are confined to the north-eastern corner of the district, where they form, as already pointed out, the main mass of the Nagari group of mountains, the Tripatti hills, and the extreme south end of the Vellakonda range. The remarkable and highly picturesque scenery of this region is due to the great mural scarps into which the massive quartzite beds have been worn.

Chief outliers.

The Nagari mountains form several outliers detached from the main area of the Kadapa rocks, of which the Tripatti hills and the end of the Vellakondas form the southernmost extremities. The principal outliers are four in number, the Nagari Nose mountain forming the most southernly of the number. North of this is the Narnavaram ridge, a long

narrow ridge lying north-east of the village of Narnavaram, and not to be confounded with the Narnavaram peak, which forms the southern end of a large outlier which includes the Saddashemallai or Sathuskonda, the highest member of the Nagari group, and the mountains south of Kálabástri (Calaetsy). The fourth large outlier includes the Ránsagiri and the Kambákam (Cumbaucum) Drug mountains.

Petrological characters.

Many of the quartzite beds which rest on the gneiss in marked unconformity are coarsely conglomeratic, including pebbles of gneiss, quartz, and occasionally of ribbon jasper. The quartzites are generally very massive, and semi-vitreous in texture, and occur in thick beds which often show but little lamination. The surface of some of the beds is often covered thickly with small annular markings, as if they had been stamped all over with an ordinary wad-cutter. No satisfactory explanation of the cause of these markings had yet been offered. In some beds the rippling caused by current action has been beautifully preserved.

The prevalent colors of the quartzites are pale greys and drabs, all weathering to shades of buff or pale orange. The principal lines of scarp face the south, *e. g.*, those of the Nagari Nose, the Narnavaram peak, the Saddashemallai, and the Tripatti mountains, but very fine east and west scarps are seen on the Ránsagiri. The three scarps first mentioned are in many parts quite vertical, and form perfectly bare walls of rock from a few hundred to over a thousand feet in height. The smaller outliers show some of the lowest beds, but are of no special interest.

The whole of the beds exposed in the North Arcot district belong to the second lowest of the divisions recognized in the Kadapa series by Mr. King[1] and called by him the Nagari series, a yet lower series underlying the Nagari beds having been recognized by him further north near the Papagni river in Kadapa district.

The most southerly recognized outcrop of the Kadapa beds is the Nagari Nose mountain, but it is not improbable that some large detached masses of quartzite occurring at the base of the Gondwána rocks at Naikenpalem, eight miles further south-east, ought to be regarded as relics of the basement bed of the Nagari group. These masses of quartzite will be referred to again further on.

THE UPPER GONDWÁNA SERIES, RAJMAHAL GROUP.

The great series of rocks known under the name of the Upper Gondwána, which occupy a very important position in the northern half of the peninsular area, are represented in the Madras region by considerable formations of great interest, because they contain fossil plants, some of which are identical with those occurring in the Upper Gondwána formations of the Rajmahal hills in Bengal.

Their representatives in North Arcot occur in two positions, one north, the other south of the Pálár. In the first wo may conveniently distinguish three localities, the Sattavedu, the Alikur (Alcoor), and the Pyanur areas; in the second there are some twenty-five small patches scattered widely over the surface of the gneissic area in the Arcot taluq, a few miles south-west of Con-

[1] See Memoirs Geological Survey of India, Vol. VIII.

jeveram. The most important and the greater number of these patches lie around the great Mámdur (Maumdoor) irrigation tank, and hence the group may be conveniently called the Mámdur group. Three small outlying patches occur twenty miles further to the south-west in the Arni zemindari. This group of small patches are evidently the remnants of a once extensive spread of the Upper Gondwána rocks, which, in all probability, was continuous with the beds of the same age to the north and north-east, and very likely also extended far enough southward to join the Utatur (Ootatoor) "plant beds" in Trichinopoly district.

Great denudation, especially in the area south of the Pálár, beginning probably in precretaceous times, separated the Gondwána rocks into the many detached outliers now enumerated, while their surface is largely obscured by the overlying younger lateritic and alluvial formations.

Division into two groups.

As before mentioned, the Upper Gondwána beds of the Madras region have been divided into two groups, called after the localities in which best developed, the *Sattavedu* and *Sripermatur* groups; the division is chiefly based on petrological differences, the actual stratigraphical relations being very obscure and somewhat doubtful owing to the insufficiency of existing sections.

The Sattavedu group.

The Sattavedu group, which consists mainly of coarse, well consolidated conglomerates and sandstones of great thickness, forms the mass of the Sattavedu and the northern and eastern parts of the Alikur hills, while beds of uncompacted conglomerate with intercalated clays and shales appear to underlie the hard Sattavedu beds in the western and southern parts of the Alikur hills. Unfortunately no section exists (or existed) showing the two sets of beds in actual contact, hence their stratigraphical relations are still doubtful.

The Sripermatur group.

The soft beds have been referred provisionally to the 'Sripermatur group on petrological grounds, the resemblance of the softer rocks being much stronger to the rocks found in the Sripermatur outcrop in Chingleput district, than to the coarse and compact conglomerates and sandstones of the Sattavedu and eastern Alikur hills.

The Sattavedu area.

The whole of this outcrop is made up of alternate bands of hard conglomerates and sandstones, many hundred feet in aggregate thickness, and of more or less red color. The conglomerates are made up of large well rounded smooth quartzite pebbles, with a small number of similar pebbles of granite gneiss, the whole strongly cemented by a matrix of variable character, sometimes argillo-ferruginous, ferrugino-arenaceous, or more rarely siliceo-calcareous. The sandstones are mostly rather gritty in texture, and contain here and there a few plant remains, among which Mr. King found a frond of *Dictyozamites indicus*, one of the most characteristic Rajmahal plants. The beds have a generally eastward dip at moderate angles. The area of the outcrop is nearly co-extensive with that of the hill group, and measures about sixteen miles.

The Alikur area.

The Alikur area is separated from the foregoing only by the narrow alluvial valley of the Narnavaram river, under which the beds are doubtless continuous. The eastern half of the Alikur hill group consists of hard conglomerates and sandstones, apparently continuations of

the beds forming the south-western part of the Sattavedu hills. Like these they have a more or less easterly dip, and disappear under the lateritic beds, which lap round the eastern foot of the hills, and which, together with the great talus which has accumulated on the base of the slopes, completely obscure all the relations between the lower and upper rocks. No fossils were found in the Alikur hills. The hard beds occupy only about a third of the area of the Alikur outcrop, the remainder being formed of the soft beds assumed to belong to the Sripermatur group, and which, as already mentioned, appear to underlie the hard beds conformably. No section was found showing these two dissimilar series in contact where they approach each other in the centre of the Alikur hill group, but as far as the rounded outlines of the hills at that point serve to guide the eye, there is an undoubted dip of the softer beds under the hard conglomerate. No sign of any fault could be traced, but from the peculiar nature of the case, a fault of great importance might well exist, and yet be completely hidden by the vast quantity of debris and talus which everywhere almost cumber the surface even of steep slopes. The nearest visible approach of the two series is a short narrow east and west ridge abutting at right angles against the hard basement conglomerate of the Sattavedu series, which here forms a conspicuous north and south ridge parallel with several of similar character further east, each representing a great conglomerate bed. The valleys running down north and south from the cross ridge are the two principal ones in the central mass of the hills, and their depth, which is considerable, is due to the greater softness of the underlying beds as compared with the overlying set.

The soft beds so frequently named consist of conglomerates, gritty clays, and shales of white or grey colors. Even the coarsest conglomerates at the very base of the series are uncompacted and soft, the enclosed pebbles and boulders of gneiss and quartzite merely lying embedded in very friable more or less clayey grit consisting of quartzose debris of gneissic origin. The slopes of the hills composed of such soft beds are deeply covered by debris, while but few of the rain gullies descending from higher slopes penetrate sufficiently to expose the rocks *in situ*. The Naikenpalem hills, which occupy the southern part of the Alikur area, consist, as far as seen, entirely of the soft beds which have trended round from a north and south strike in the Alikur hills to one running west-north-west to east-south-east.

Numerous plant remains were obtained from a clay bed exposed in one of the principal rain gully sections east of Naikenpalem village. Amongst the remains were parts of *Tæniopteris*, *Dictyozamites*, *Ptilophyllum*, &c., all characteristic Rajmahal plants. Unfortunately the specimens, which are beautifully distinct when freshly extracted, are utterly ruined by the shrinkage of the wet clay as it dries.

Included masses of quartzite.

Near the village of Naikenpalem the basement bed includes enormous masses of conglomeratic quartzite, some of them from 800 to 1,000 cubic feet in bulk; these are very probably relics of the basement bed of the Kadapa series, which is so generally represented a few miles to the north-west and north in the great scarps of the Nagari mountain and the Ramagiri. These great quartzite masses are not seen resting actually on the

gneiss surface, but it can only be a few feet below the local surface of the slope; it is only reasonable, therefore, to look upon them as ruins of the once existing conglomerate bed forming locally the base of the Kadapa rocks, which was nearly all removed by denudation. In view of the enormous amount of denudation the shapes of the Nagari mountains show them to have undergone, there can be no difficulty in accepting this solution of the problem. If the blocks be not, however, really *in situ*, their existence in their present position is even more remarkable, as no known agency, but that of floating ice, can explain their presence. The appeal to glacial agency in such a southerly latitude would not be justified except on the very strongest evidence.

The Pyanur area.

The character of the rocks in the Pyanur area changes slightly, the included boulders and pebbles in the conglomerates are more frequently of gneissic origin and less exclusively of quartzite. They are embedded in equally soft and uncompacted beds. Fossils are very rare; none were found except in a friable sandstone exposed in the left bank of the Nagari river opposite Chittapuram, a little below the junction of the Trittani river. Fragments of *Tæniopteris* and *Dictyozamites* were here obtained.

The basement conglomerate in many parts of the Pyanur area was deposited around and includes large water-worn masses of gneiss forming boulder beds similar to those occurring in the base of the plant beds at Utatur and elsewhere in Trichinopoly district, and similarly at various places in the Ongole group of outcrops in Nellore district.

The hard white and mottled shales so typical of the Sripermatur group in its proper basin do not occur in any of the outcrops in the Arcot district, but some of the clays exposed in the south-eastern corner of the Alikur area show signs of passing into a shaly condition, and appear to do so further to the north-east in the valley of the Alikur nullah.

Mámdur patches.

Outcrops south of the Pálár.—The petrological features of the southern or Mámdur group of outcrops, as well as their geographical proximity, justify their being assigned to the Sripermatur division of the Rajmahal beds. As they were visited only by the late Mr. C. Æ. Oldham, it will be better to quote the description, as far as possible, in his own words as given in his notes.

Thechur outlier.

The three most westerly outcrops, which have already been mentioned as lying about twenty miles south-west from the Mámdur group, are situated close to the village of Thechur, seven miles south of Arni. Here to the south-west of the village occurs a "greenish-yellow shaly sandstone," which "is also dug out from wells in the village." "East of the village I noticed another minute patch."

Conteantandalam.

Of the patches forming the Mámdur group, Mr. Oldham remarks in his notes: "At Conteantandalam, the most easterly of these localities, several wells and bowries, in and near the village, expose about 12 feet of these beds," which are chiefly a soft yellow sandstone thick-bedded, but in the lower portion some harder compact beds occur; and a coarse conglomerate containing numerous pieces and pebbles of quartz and gneiss in a hard silicious matrix has been quarried to some extent from under the soft beds.

After mentioning a narrow and thin slip of hard ferruginous sandstone close to the ford by which the Conjeveram-Wandiwash road crosses the Pálár, Mr. Oldham describes the interesting outcrop at Doshi (a mile and a half to the south) thus:—"This locality and its immediate neighbourhood, though not affording even a single tolerable section, yielded to me the great majority of the fossil specimens, all plants, which I succeeded in procuring from this series of beds." "In a small tank west of the village I noticed a little yellow sandstone in flat beds just appearing above the surface of the water when low, and from the bund of this tank, which is largely composed of the pieces of this and other beds thrown up when it was dug, I succeeded in obtaining numerous plant remains." "I could not discover a trace of mollusca or other animal remains, but in some of the beds of sandstone the plant remains are very abundant."

Doshi outcrop.

"Until they have been more carefully examined and compared, I cannot attempt to do more than indicate their general character, which is very similar to that of the Rajmahal flora, presenting *Palæozamia* (*Ptilophyllum*), *Tæniopteris ? Stangerites* (*Angiopteridium*), *Pecopteris*, and *Sphenopteris*." "I obtained also specimens of circinnate vernation of ferns. These remains occur in great abundance, principally in thin-bedded yellow sandstones, but some of them also in a coarser thick-bedded sandstone." "This strip of sandstone has its limits narrowly defined by the appearance of gneiss *in situ* closely on the east, north, and south, and at no great distance on the west also."

Plants found.

"About four miles west of Doshi is the best section seen of these beds. This is exposed in the old supply channel which runs from the river Pálár near Umiaveram to the large Mámdur tank, in the banks of which and the small watercourse adjoining a fair section is exhibited, showing a greater thickness of beds than I was able to discover in any other locality." "Proceeding southward along the channel we get the following section. The first (lowest ?) bed seen is a coarse white felspathic sandstone with small pebbles of quartz, from 3 to 4 feet in thickness, rather soft and scarcely consolidated, at least superficially. I could here detect no organic remains whatever. Over these lie about 3 feet of a finer yellowish sandstone with minute shaly partings of a greyish-white color." Above this are 5 feet of a hard ferruginous sandstone, the uppermost bed of which has a curiously tesselated appearance due to concretionary structure, assuming generally a pentagonal arrangement. All these beds have a low dip of 2° or 3° to the south and south-south-west. "Passing onward the section in the channel is broken and obscured by soil, &c., but the missing portion seems to be, at least in part, supplied by the smaller gullies, watercourses, &c., on either side, which show a few feet in thickness of yellow and white sandstone apparently overlying the ferruginous bands and dipping south-by-west at an increasing angle. Proceeding still southward along the channel, we come upon a hard brown ferruginous sandstone dipping south-south-west at 32°. Of this only 2 feet appear, and over this from 20 to 25 feet of a soft rather coarse yellow sandstone with a few harder ferruginous partings, all dipping south-south-west at from 30° to 35°. Over this with a dip in the same direction, but at gradually decreasing angles,

Mámdur section.

are rather coarse clunchy yellow sands, thick-bedded and only moderately consolidated. Of these about 25 feet appear overlaid by about 10 of thinner-bedded yellow sandstones of much finer grain with thin greyish shaly partings. These are apparently the highest beds[1], shown in this section, as on proceeding along the channel we find them turning up with a considerable dip of 25° to 30° to north and north-by-west." From under these again appears the coarser thick-bedded yellow sandstone which continues to show along the channel for a distance of about 200 yards, with here and there some of the thinner beds appearing in the banks above. Still following the channel, as it turns south-east and east-south-eastwards, these coarser beds continue to appear, having a rolling dip to the north-north-west." From under these rises with westerly dip a strong brown ferruginous sandstone which only shows for a short distance, and is the last and lowest bed seen in this direction, disappearing at a point due north of Namdi (Naumdee), a quartzo-hornblendic gneiss appearing a very short distance to the east. A yellow sandstone very similar to the upper beds of the section just given appears in bowries and in a little watercourse north-west of Namdi.

The small outcrop west of Tallicalli and north of the channel section just described shows coarse pebbly ferruginous sandstone. The outlier west-by-north of Tripnagad and that south of Umiaveram show coarse, white felspathic sandstone, associated, in the latter case, with a little thin-bedded ferruginous sandstone of brown color. At Cutanur, two miles to the west of the last-named outlier, a greenish-yellow somewhat shaly sandstone underlaid by a coarser yellow felspathic sandstone is exposed in well and tank sections. A coarse ferruginous sandstone forming a small patch at the north end of the Manapakam tank, four miles south-west of Cutanur, is the most westerly extension of the Gondwána rocks in this quarter.

Three miles further south-east and east of the village of Asuapetta, and again a mile to the south of the village, "we find patches of hard conglomeratic sandstone containing large pebbles of quartz. This is superficially ferruginous and of a reddish-brown color, but when freshly broken of a dull grey. It lies in thin beds on the surface of the gneiss."

Jaderi section.

Proceeding south "along the road between Asuapetta and Trivatur, we cross four distinct patches of sandstone, in the most northerly of which a tolerably good section is exposed in a supply channel running in to the tank at Jaderi (Bathary"). Here resting on the surface of the gneiss is a hard very silicious close-grained sandstone, but frequently containing large pebbles of quartz. Of this there is a thickness of several feet, showing only at intervals and not well seen. Above this, passing east along the channel, we find a coarse felspathic sandstone of no great thickness (2 to 3 feet),

[1] "From these highest beds I procured the only specimens of organic remains that I was able to secure from this locality. Owing to the soft, crumbling nature of the rock, much increased by heavy rains which had fallen recently, it was almost impossible to obtain specimens that would bear carriage. Several which I extracted came to pieces in my hands. Those which I succeeded in carrying away were *Palæozamia ? (Ptilophyllum)* and *Pterophyllum ?* I noted also *Tæniopteris* and *Pecopteris*."

with locally a fine grey shale, in which some fragmentary stem markings were noticed. All these have a low dip of 2° to 3° east." Above all is a ferruginous sandstone, 1 to 1½ feet thick and of rather coarse texture.

Small outcrops north of Trivatur.

The other three patches which are seen crossing the road consist of a hard superficially generally ferruginous sandstone, similar in character to the lowest bed of the above section. A patch of similar beds covered by a little yellow sandstone occurs east of the road about two and half miles north of Trivatur. Between three and four miles north-east of Trivatur and east of Perintur occurs a little hard grey sandstone, about 10 feet thick and weathering of a reddish-brown.

Three miles to the north close to Mariannr, a large amount of debris of a reddish ferruginous sandstone covers the ground, and close to the village on the south this is seen *in situ* overlying a coarse brown felspathic sandstone, of which but little is seen, though it has been thrown up in considerable quantity from well and tank sections. In the village a tolerably hard yellowish-brown sandstone is dug out of bowries (large square wells) and has been used to a small extent for building. A similar brownish-yellow sandstone is also dug out at Shamanguri, two and half miles to the north-west.

A few more small patches might be referred to, but they offer no special characters of interest.

The numerous patches just referred to are, without exception, of small size, the largest not being more than two miles long by one in width at its widest part, and the great majority greatly less in dimensions.

THE LATERITIC FORMATIONS.

Of the numerous spreads of the lateritic rocks which fringe the eastern coast of the peninsula between Latitude 13° 50′ and 11° 20′ north, only a few extend inland sufficiently far westward to come within the limits of the North Arcot district. There is, however, abundant evidence that these rocks had formerly a much wider westerly extension, and that their present western limits are boundaries of denudation and not of deposition. The chief outcrops of them occur along or close to the eastern boundary of the district, and are in most cases seen to rest upon the Upper Gondwána beds, to which, however, they are markedly unconformable, and in many cases they overlap on to the gneiss. All the outcrops of importance lie to the north of the Pálár.

The most southerly patch of lateritic beds requiring notice lies between the north bank of the Pálár and the alluvium of the Kortelliar, about twelve miles east of Arcot town. It is in reality only the extreme western end of a very large lateritic area which occupies further eastward nearly the whole of the Conjeveram taluq. The prevalent rock here seen is of a red sandy variety with scattered patches of ferruginous gravel.

Shingle conglomerate.

To the north of the Kortelliar the laterite occurs in the form of an enormously coarse shingle or generally uncompacted conglomerate, such as may be seen at and to the south of the Chinnamapett railway station. Further north the surface of the Pyanur area of Rajmahal beds is widely covered with an equally coarse shingle associated with large quantities

of ferruginous gravel and clay binding the whole into a semi-compact conglomerate, which is the general character of the lateritic beds further north round the base of the Naikenpalem, Alikur, and Sattavedu hills, the coarseness of the included shingle and the amount of ferruginous cement associated with it being locally of variable quantities. Where the shingle, which consists almost entirely of quartzite, attains a great degree of coarseness the ferruginous matrix is often masked to a very great extent, the peculiar vermicular cavities so characteristic of non-conglomeratic laterite are never seen, and the correlation of the two varieties as members of one and the same geological formation is made entirely upon stratigraphical grounds.

The principal lateritic areas lying westward of the eastern boundary of the district are those along the western base of the Ramagiri and the eastern base of the Nagari mountains, and some spreads in the valley of the Swarnamukhi river near the Madras railway at Karkambadi. In the two first of these areas the rock is much less coarsely conglomeratic than around the Alikur and Sattavedu hills and over the Pyanur area.

The surface of the Pyanur laterite patch is very thickly strewn with the extremely coarse quartzite shingle weathered out of the underlying conglomerate, and in many places progress even on foot is by no means easy across the great smooth and highly slippery stones. The surface is so extremely stony that great tracts remain waste. That a very flat country should be so inaccessible owing to the thickly strewn products of partial weathering of the rocks forming the surface is a very singular phenomenon.

Debris of lateritic beds.

Remains of lateritic beds are very numerous to the westward of the present westerly boundaries of the formation. Many such remains were noted as much as six or eight miles away from the nearest of the undisturbed beds, and a closer search of the country would probably show such ruins even far further in that direction. The greater westward extension of the lateritic rocks, before adverted to, is thus abundantly proved.

Occurrence of stone implements.

Proofs that the lateritic formations were, in part at least, formed since man's advent on earth are numerously met with in the North Arcot laterite patches in the form of well-shaped chipped implements of palæolithic types made of quartzite. Many of these were discovered by the geological surveyors in nearly all the lateritic patches, and in many cases also among the debris marking the sites of the now denuded parts of the old extensions., *e. g.*, among the gravelly ferruginous debris lying in the surface of the gneiss at and around the Arkonam railway junction at an elevation of more than 300 feet above sea level.

Elevation of lateritic beds.

The highest elevations to which the implement-bearing lateritic rocks have been traced in this region are the neighbourhood of the Madras railway at Karkambadi, in the Swarnamukhi valley, and the westernmost slopes of the Naikenpalem hills; in the former case, the implements occur at an elevation of 370 feet above sea level, in the latter, at a probable elevation of between 500 and 600 feet. The Karkambadi beds yielded a great number of fine implements to the search of Mr. W. R. Robin-

son, C. E., Chief Engineer of the Madras Railway, when Resident Engineer at that place.

Age of certain shingle beds.

There can be little doubt that the great accumulations of well rolled quartzite shingle which rest on the southern bank of the Nagari Nose mountain and on the flanks of some of the mountains further north must, in part at least, be reckoned as of the age of the lateritic period, as they correspond closely in position and mineral character with the higher-lying lateritic beds just mentioned. The Nagari Nose shingle bed is deeply stained with iron from the ferruginous matrix which must have once surrounded the perfectly non-ferruginous quartzite shingle, for that is the only way of accounting for the deep and indelible purple-red color borne by the natural pale-colored quartzite. As now seen, the shingle suggests instantly the idea of its being an old raised beach.

The origin of the lateritic formations, owing to the total absence of all organic remains (the chipped implements being only indirectly of organic origin), is wrapped in obscurity and doubt. Three theories have been propounded to explain the existence of these formations which fringe the western and eastern sides of the peninsula from a little south of Bombay right round to Cuttack and still further north. The three theories have been discussed at some length, each having something in its favor, but they are still *sub judice*, and this is not the place for continuing the discussion.[1]

They may be briefly designated as the marine, the fluviatile, and the subaerial. As at present seen, none is altogether sufficient to explain the various difficulties, and it is very possible that all three must be enlisted before more light can be thrown on the subject.

The Alluvial Formations.

The alluvia occurring within the North Arcot district are all of fluviatile origin, and occupy the valleys of the principal rivers, but are developed only to a very moderate extent, and would offer no points of special interest were it not that in two cases there is evidence of the rivers having changed their courses widely and formed a second series of deposits in other valleys.

Change of course of the Pálár.

The first of these cases is that of the Pálár, the principal river of the district, which now flows into the sea forty-two miles south of Madras, but which formerly flowed down what is now reckoned the alluvial valley of the Kortelliar river and entered the sea somewhere to the north of Madras, probably between Gunore and Pulicat. A glance at the geological map will show that the present valley of the Pálár is very disproportionate in size to the river, and equally that the alluvium of the Kortelliar is greatly disproportionate to its river, which now flows in a deep channel.

[1] For the discussion of these theories, the reader is referred to Mr. Foote's papers on the subject of stone implements in Southern India in the Madras Literary Journal for October 1866, the Quarterly Journal Geological Society of 1868, p. 484, and the Memoirs Geological Survey of India, Vol. X, pp. 51, &c. Also stone implements of Great Britain by John Evans, D.C.L., F.R.S., and lastly, to the *résumé* by Mr. W. T. Blanford, in the Manual of the Geology of India (Vol. I, pp. 368-370), of the facts known about the low-level laterite.

The two valleys diverge at a place about ten miles east of the town of Arcot, and a small stream (or irrigation channel) still branches from the Pálár here and flows down the Kortelliar valley for many miles and eventually joins the latter river. To this stream the natives have given the Sanscrit name of Vridacharanadi or "old milk river," the Tamil name of the main river "Pálár," also signifying "milk river." The alluvium occupying this valley consists of coarse gritty loose silicious sand of gneissic origin.

Change of course of the Nagari river.

The second case is that of the Nagari (Naggery) river, which in former times appears to have fallen into the Narnavaram river, just south of the Ramagiri, and close to the village of Nagloperam. The present course of the river lies down the old alluvial valley for a little more than three miles east from the railway bridge. It then turns sharply south-east, leaves the alluvium, and flows through a cutting in the gneiss about a mile and a half long and falls into the Trittani river, which joins the Kortelliar a few miles further east. In consequence of this the broad alluvial valley which runs between the Nagari mountain and the Alikur hills is now drained only by small streams and artificial channels. The alluvia deposited by the Nagari river both in its old and new valleys consist almost entirely of coarse gritty sand like that of the Pálár. No alluvium appears to be deposited at present, but the streams seem to be cutting their beds deeper and deeper every season.

No information was procurable from the natives as to the time when these changes took place, but the probability is that, geologically speaking, they are of very recent date, as may be inferred in the case of the Pálár from the name given to the channel which still falls into the Kortelliar; and in the case of the Nagari river, from the fact that the cutting through the gneiss by which the river escapes from its old alluvial valley presents every appearance of being of artificial origin, and must in that case have been the work of a people boasting some considerable civilization.

THE SOILS AND SUB-AERIAL FORMATIONS.

Of the soils in North Arcot little need be said; they appear, as a rule, to be the product of the weathering of the local rocks, or to have been brought from but trifling distances by pluvial action. The prevalent soils are red, and of these the sandy form is the most common.

Of the sub-aerial formations the only really interesting and important ones are the taluses around the quartzite-capped mountains in the north-eastern corner of the district. As already pointed out, the talus accumulations are two-fold, and consist partly of great collections of well rounded shingle referable to the lateritic period, and above them of the angular unrolled debris detached from the great scarps by atmospheric agencies, which debris here now shows the deep ferruginous stain characteristic of the lateritic shingle beds. On a greatly smaller scale, but still of considerable importance, are the talus accumulations on and around the newer Rajmahal and lateritic formations in the Sattavedu, Alikur, and Pyanur areas. These consist in both cases almost entirely of well rolled

quartzite shingle weathered out from the many important conglomerated beds occurring in both series.

ECONOMIC GEOLOGY.

The information on this branch is not so complete as might be wished, owing to the non-completion of the survey of the district. The granitoid gneiss occupying the greater part of the gneissic area offers nothing but building stone; but of this much is of great beauty and value, and has been very largely used for many large native buildings, as the forts at Vellore and elsewhere, and among European buildings, particularly in the construction of many railway stations, bridges, and culverts.

Kaolin.

The highly felspathic varieties of the granite gneiss are occasionally so greatly decomposed as to appear to offer sources for the collection of kaolin or China clay. When carrying on the survey of the Vellore and Eudialtham taluqs, I noticed various spots which appeared to me to be deserving of attention with this object till I had seen some of the great China clay works in Cornwall, which I visited specially for the purpose of study when at home in 1868.

The conclusion I then came to was, that none of the North Arcot localities showed rocks sufficiently rich in decomposed felspar to be of much importance. The extent to which the Indian rocks have been penetrated by decomposition is greatly less than the Cornish rocks, and the quantity of clay which would therefore be procurable in India would, area for area, be greatly smaller than in Cornwall. Added to this very serious disadvantage is the difficulty of a suitable water-supply. To insure the preparation of kaolin of good color, which alone commands a high price, a very large supply of perfectly limpid water is a *sine-qua-non*. This is not always easy to obtain even in a rainy climate like that of the south-west of England, where running streams are of frequent occurrence, and in a dry climate like that of the Carnatic, this want could only be met by the construction of special reservoirs of large size, in which the water could be allowed to stand for many months after the rainy season, till all the suspended particles of ferruginous clay had settled, and the water itself has become perfectly limpid. If the great cost of providing such supplies of limpid water free from saline matter in an eminently dry country be taken into consideration, together with the fact that the kaoliniferous decomposed rock occurs in greatly smaller quantity, and is generally much less free from ferruginous staining due to the filtration through the almost universally overlying red soil, the conclusion seems inevitable that the prospects of establishing profitable China clay works in North Arcot are not very promising.

Building stones.

To return to the subject of building stones: the rocks of the gneissic series alone offer an inexhaustible supply, and localities which would yield first rate material in any quantity might be enumerated by the score, if needful. The mention of only a few must, however, suffice; these are Palikonda hill, Vellore, Wandiwash, and Chitpat, south of the Pálár, and Ranipet, Sholinghur, and Trittani, north of that river.

The quartzites of the Kadapa series are too hard and expensive in working to

be used except as rough building stones; and the sandstones of the Rajmahal beds are not hard enough, except in a very few cases, to be of much value. Neither Mr. Oldham, Mr. King, nor myself came across any that were fit for first class purposes, such as millstones or grindstones. Nor were any of the clay beds noted in the Alikur and Pyanur areas of sufficiently good color to be of much value. The pottery clays used by the people are taken from the younger lateritic or alluvial deposits, and are, as a rule, of very inferior quality.

ON THE CONTINUATION OF THE ROAD SECTION FROM MURREE TO ABBOTTABAD, *by* A. B. WYNNE, F.G.S., *Geological Survey of India.*

In a former paper (Vol. VII, p. 64), I described the section from Murree to Kalabagh Post, along the upper or military road through the *galis* ("gullies"), as it is usually called.

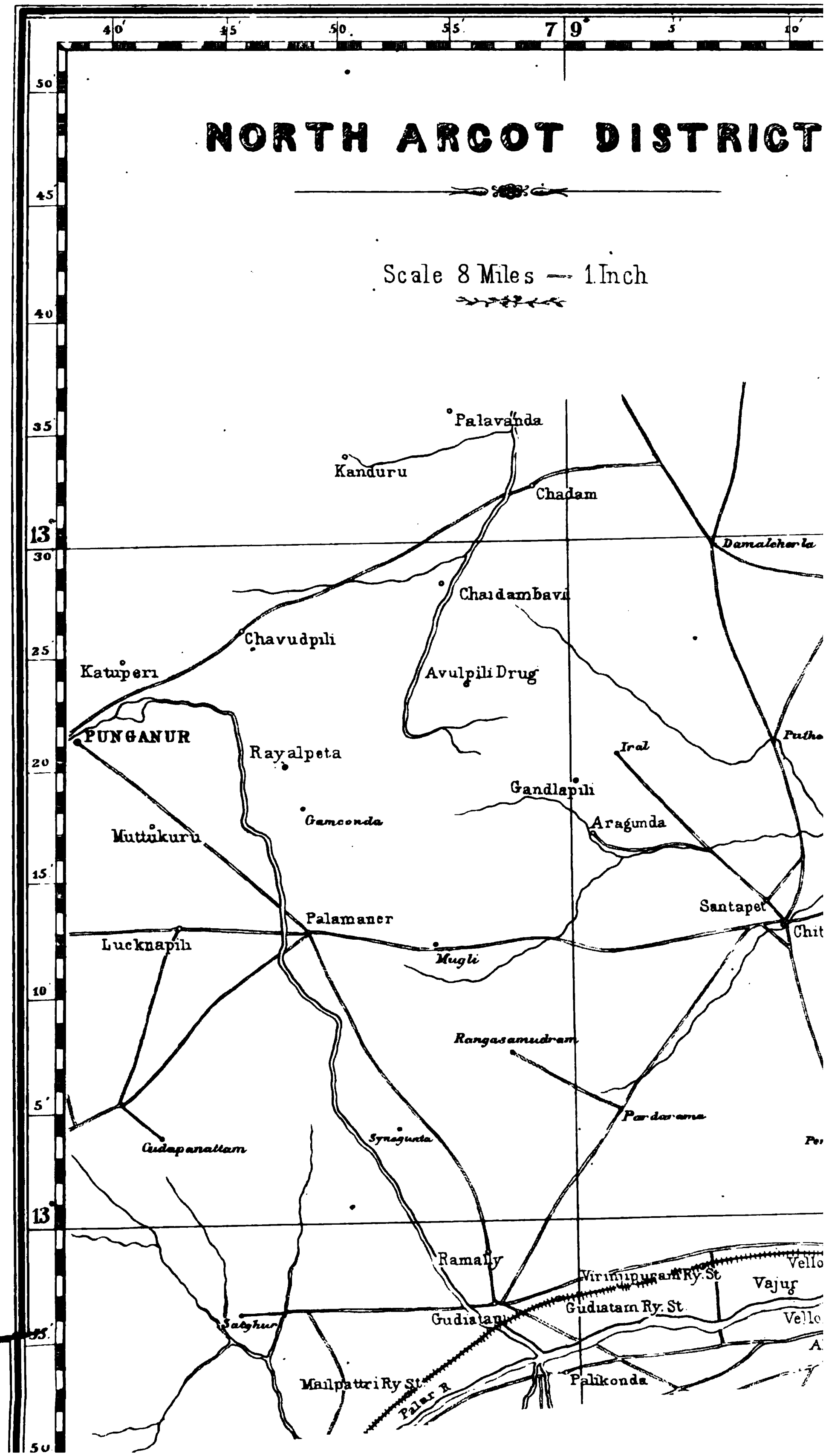
At Kalabagh, the summit level of this road (about 8,000 feet by aneroid), the nummulitic limestone and shales of the hills are in junction with the azoic Attock slates of the Mian-jani-ka Chowki range, this junction being apparently effected by means of a fault concealing all of the intervening rocks that may be present. The slates are much folded and, about half way between Kalabagh and Baragali, include a band of the usual frilled, dolomitized, seemingly slightly altered and entirely unfossiliferous limestone found elsewhere in these slates. It extends in the strike across the ridge supporting the road, and similar bands may be seen projecting at the surface of a spur from Mianjani mountain, and forming the crest of another ridge running out westward from Baragali, in both cases with a northerly dip. Near the last-named place the slates contain bands of hard dark grey or bluish silicious sandstones, and further on down the steep incline to the northwards at Bantangi purplish-red slab-slates occur near the junction with the limestones of the northern side of the great Mianjani slate tract.

The junction here differs from that at Kalabagh, but has scarcely less the appearance of a faulted or dislocated contact, the plane of which is partly vertical and partly sloping to the north, for on the western side of the Batungi Kad, the limestone, almost entirely concealed by dense forest, slopes upward and backward to the south, while the whole hill face on the opposite side of the Kad is of slate, as usual crushed, contorted, and folded.

Just at the contact, where a purplish color pervades the slates in some places, the next adjacent rocks are vertical light-colored quartzites, of small thickness, succeeded by compact and sandy limestones containing many impressions and sections of brachiopods, mostly of small size, many of them resembling casts of *Terebratula;* some obscure spiral gastropods, and some layers crowded with the curved fragments of small bivalves also occur. These hard limestones have nothing beyond the most general similarity to the hill nummulitic limestone beds; they are often dark or nearly black, and some of the bluer layers present a curious but characteristic yellow-mottled appearance frequently observed in the limestones of the Dungagali and Changlagali road, where these

Foote.

GEOLOG



have been supposed of triassic age, for which, however, there seems little more than a conjecture on the part of Dr. Waagen, as the fossils, when the beds contain any, are mostly very obscure. Other beds show a tangled mass of fucoids on the surfaces. These limestones are largely distorted, forming at first a complex synclinal curve crossed by the throat of the Batungi gorge. Before leaving this narrow part of the gorge and turning eastwards towards Bagnotur, the road crosses a small hollow in the limestone hills north of the synclinal arrangement of the beds. In the hollow and on the slopes on the opposite side of the Kad some small *dogas* or field terraces show the waste of dark shaly rocks, so that possibly some fragment of Spiti shales may here occur, to mark a boundary. Beyond this hollow and until the road has curved eastward, the dark limestones become more like the lowest of the nummulitic ones; they contain disseminated and nodular pyrites and a thin band or bands of very dark coloured ferruginous clay with rounded quartz grains and spangles of mica, but no fossils could be detected. Just at the turn some broken and detached portions of what may once have been a more continuous layer of dark ferruginous oolitic hematite clay is enclosed among the limestone beds. It has slight resemblances to the golden oolite of the Salt-range and Kach, but is not identical with that rock. A little way beyond it the limestone, if it has any general dip, slopes southerly, and the first distinct traces of nummulitic fossils appear in foraminiferous forms distinguishable with a good lens, amongst them the little organisms referred to in a former paper (Vol. X, p. 114), and tiny *Rotalina*-like forms, as well as little nummulites, most of which might escape observation with unassisted eyes.

At Bagnotur one has descended some 3,230 feet (aneroid) from Kalabagh, within a distance of five miles by the road (much less in a straight line), and just before reaching the bungalow or rest-house, the Attock slates again appear, occupying, beneath enormous masses of debris, the lower part of this valley and that of the river Dore coming from the eastward, which here unite. The slates continue in this position, chiefly on the south side of the Dore valley, uniting eastward with the main mass of the Mianjani exposure, so that the limestones just now mentioned form a tongue stretching in the direction stated from those occupying much of the northerly parts of the lower Hazara hills. As it is the nummulitic part of these limestones which occurs in junction with the slates and not one of the older groups, it may be presumed the contact here again is effected by a fault.

Following the Abbottabad road from Bagnotur downwards to the bridge over the Dore, 670 feet below the bungalow, another apparently faulted junction with the limestones is crossed before reaching the lowest point. These limestones dip north-westward, are strong-bedded, compact, and of dark-grey colour, containing small fragmentary fossils, amongst which I observed the basal portion of a shark-like fish tooth. They are sometimes semi-oolitic, and sometimes contain knots or blebs of carbonate of lime, the whole assemblage having the aspect of the supposed triassic limestone of these hills.

Where the Dore bridge spans the chasm below this point, similar limestones dip at high angles to the eastward, and rising from the bridge high over the northerly channel of the stream, they are seen to include a 10-foot band of

purple and light-coloured ferruginous shale lying between dolomitic and dark lumpy bands. Further on dirty brown limestone is full of shell fragments, and again solid limestone alternates with shaly bands.

This gorge is the most profound traversed by the road; on one of the mountains close to the westward, overlooking it, a height is marked of 6,645 feet; and supposing the stream to be 4,200 feet, the section exposed in the steep mountain side may be nearly 2,000 feet in height. The rocks for about a mile in the narrow part of this gorge are all of the triassic aspect just now described, and they are seen to be contorted in the wildest fashion, a group of hard beds showing their edges vertically for some hundreds of feet, and standing as it were upon a strong horizontal outcrop below, as well as presenting in other places a variety of compressed curves. Leaving the narrow part of the gorge and descending into the valley of a small tributary from the east, the Attock slates are again exposed, forming a small denuded inlier, beyond which northwards crags of the disturbed triassic-looking limestone reappear. Just beyond this, the Dore river bends to the west, and in its further bank (the left), there is an exposure of black Spiti shale with fragmentary Ammonites and many Belemnites as usual. From this onwards, the road rises high above the right bank of the river, and passes along cuttings in much contorted nummulitic limestone, with two or three exposures of black coaly or carbonaceous shale, associated with ferruginous and quartzite sandstone. Black shales are also seen cropping out at the lower part of the limestone cliffs on the opposite (southern) side of the river.

As the valley opens and the road enters the little flat of Damtour, limestones of triassic aspect come out from under the nummulitic ones, and form the face of the hill east of the village. Beneath these limestones are seen the Attock slates with a high easterly dip, and the lowest bed of the limestone series above, resting directly upon the slates, is a sandy conglomeratic one enclosing fragments of the underlying slate group, as observed in the Sirban mountain sections; but it is worth notice that the largely developed masses of red sandy or earthy ferruginous beds and greyer silicious dolomites representing the Infra-trias group of that adjacent mountain are here absent.

From Damtour onwards the road passes among and over the deep detrital deposits of the Abbottabad plain.

The mountains to the eastward repeat, with numerous disturbances and dislocations, the features of the Sirban mountain section, described in Memoirs Geological Survey, Vol. IX, Art. 3. The Spiti shales are locally more largely developed, and likewise fossiliferous *Belemnite* and *Ammonite*-bearing sandstones, which may be a portion of those referred to the Gieumal group. The Infra-trias cherty dolomites are largely present in the northern parts of these mountains, but appear to be capriciously distributed, sometimes alternating with sub-fossiliferous bands having entirely the triassic aspect, and in places occurring in some force before they rather suddenly disappear to the southwards. Their connexion with the Tanol group of Hazara is strongly suggested by the sections in the northern parts of these hills, and will be referred to in a separate note.

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Coal-shale with *Glossopteris*, same locality.
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Eight specimens of minerals and rocks (all metamorphic) from above 8,000 feet on the Safed Koh, near Gandamak.

MAJOR H. C. B. TANNER.

White quartzite, highest peak of the Safed Koh.
White marble from Safed Sang.
Soapstone, Terakai hill summit, above Murkekhel.

G. B. SCOTT, ESQ.

A collection of rock fragments and pebbles, many rolled and imperfect fossils, and small samples of soil from between the Khojah Pass and Sugari Barkhan. (See Pro. Asiatic Society, Bengal, June 1879.)

LIEUTENANT R. C. TEMPLE.

Geological specimens, mostly small rock-fragments and some fossils, cretaceous and tertiary, from Southern Afghanistan. (See Pro. Asiatic Society, Bengal, August 1879.)

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RECORDS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. XIII.

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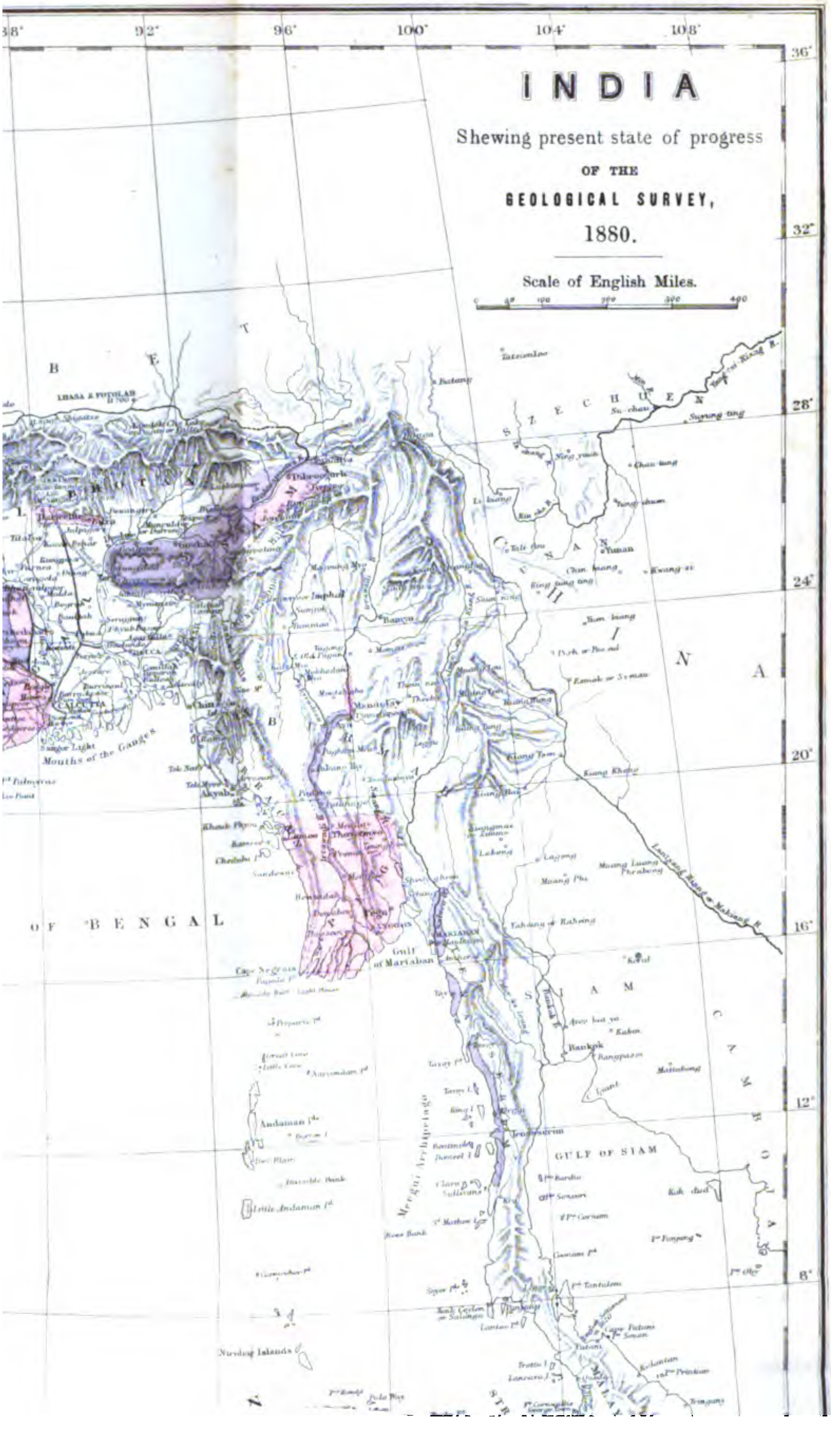

INDIA
Shewing present state of progress
OF THE
GEOLOGICAL SURVEY,
1880.
Scale of English Miles.
36°
32°
28°
24°
20°
16°
12°
8°
92°
96°
100°
104°
108°
OF BENGAL
Mouths of the Ganges
CALCUTTA
Imphal
Mandalay
Gulf of Martaban
GULF OF SIAM
Bankok
Andaman I^ds
Little Andaman I^d
Mergui Archipelago
Tenasserim
Pegu
Nicobar Islands
Cape Negrais

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1880. **[February.**

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1879.

In the *Peninsular area* there were five survey parties at work during the field season of 1878-79.

S. India: *Mr. Foote.*

As announced in the annual report for 1878, Mr. Foote took up new ground to the south of Trichinopoly, to trace out in that direction any remnants of the deposits of various ages already known along the coastal region to the north. He carried his work through the Pudukotai State to the latitude of Madura, but nothing of interest was found. The irregular boundary of the gneiss occurs at a distance of about 35 miles from the coast, and the intervening ground is principally occupied by the lateritic formation, overlying and closely connected with the Cuddalore-sandstone group, first described by Mr. H. F. Blanford in the Trichinopoly area. Its exact age is still undetermined—probably older tertiary. The laterite overlaps it to the west, and rests on the gneiss. Mr. Foote's account of this ground is published in the August number of the Records.

Mr. Foote's map and description of the North Arcot district, published in the Records for November, were compiled from observations made many years ago by himself and other members of the Survey.

Godavari: *Mr. King.*

In the Pranhita-Godavari area, besides the general extension of his survey of all the Gondwána rocks of that basin, Mr. King has fairly succeeded in maintaining a distinction of upper and lower in the Kota-Maleri series, so far as established by overlap, which is still the principal feature of unconformity between the several groups of the Gondwána system. Within the local basin we are indeed still unable, as was shown by Mr. Hughes (Records, XI, page 29), to demarcate the groups closely, but Mr. King has found that to the south there are no representatives of the Maleri clays between the Kota beds and the Sironcha sandstone, which he now recognises as belonging to the Kámthis (lower Gondwánas). The conjectured intercalation of the peculiar fossils of the two zones has not been confirmed, so as to modify this stratigraphical indication; and thus the original distinction indicated by the liassic fossils of the Kota beds and the rhæto-triassic fossils of the Maleri clays stands for the present confirmed. (*See* Pal. Ind., Ser. IV, 2; Manual, p. 151.)

SON BASIN: *Mr. Griesbach.*

In continuation westwards of Mr. Ball's survey of the Aurunga and Hutár coal-fields (Memoirs, XV, Pt. 1), Mr. Griesbach, during last field season, mapped and described some 900 square miles of Gondwána rocks in Ramkola, between Tatapáni and the Rer river (his Memoir is now at press, as Part II of Vol. XV). This ground is the easternmost prolongation of the great central area of South Rewah or the Son, extending westwards to near Katni on the Jabalpur railway, and south-eastwards into the Mahanadi basin, to near Sambalpur.

In the report for last year I gave a brief discussion, based upon Mr. Ball's description, of the stratigraphical features of this region as the transition ground between the well-marked divisions of the lower Gondwána series in the Damuda valley and the conditions found in the midland areas, where the higher groups of the lower Gondwánas, as in the Kámthi and Hingir beds, exhibit more the petrological characters of the upper part of the series. It seemed as if in the Hutár field and locally in the Aurunga field, we already had this condition established; and I pointed out that we only awaited the discovery of lower Gondwána fossils in the overlying sandstone here to make certain of it, and hence to draw some important inferences regarding the horizon of the top sandstone ("upper Panchet") of the Damuda fields. It seems, however, that we shall have to look farther west, within the midland area itself, for the facts of this stratigraphical change. Mr. Griesbach has traced a Raniganj group, with good fossil characters, and a Panchet group less distinctly, at and west of Tatapáni; but these have been reclaimed chiefly from the low-lying outcrops previously supposed to be all of the Barakar group,—not from the hill-forming sandstone, from which the upper (? Panchet) beds are not easily separable. Mr. Ball gave in his map of the Hutár field an indication of the possible position of an intermediate group.

A principal object in sending Mr. Griesbach at once to a typical Gondwána area was, as mentioned in last annual report, that he might elucidate the supposed similarity between these rocks and the Karoo formation of South Africa; indeed this object was of much weight in recommending his appointment to the Survey. In this respect his memoir on the Ramkola coal-fields will be found disappointing, the more so as it shows him to have considerable proficiency in the art of geological surveying. Mr. Griesbach has reserved his observations on this point for a still wider comparison in connection with his more recent work in the Himalayas, of which a notice will be given in the Records for May. He has verbally stated that the Tálchir boulder bed bears a very strong resemblance to the Ecca beds of Natal, and his descriptions exhibit more strongly than any yet given some of the glacial characters of the boulder bed; but he refrains from any expression of opinion on this much-vexed question.

It will be seen that the map of the Ramkola fields exhibits a free use of faults, therein resembling other maps of similar ground. The practice is quite legitimate, faults being a very common feature in such rocks; but it is capable of abuse, and it has often seemed to me that this limit has been passed in our descriptions of these Gondwána basins. A main boundary is represented as a fault, without a word to qualify all the inferences that would follow from the simple use of that word. Thus, as to the throw of this fault, that it amounts at least to the

total thickness of the strata on the downthrow side. No *á priori* objection could, indeed, be made on this count, for faults of very great throw are fully established; it is the discrepancy of the fact with other features of the description that calls attention. Thus, immediately on the upthrow side of such a fault, or near it, patches of the highest beds of the downthrow series may be seen resting on the base-rock, which fact at once makes the fault in its *primâ facie* aspect impossible. When attention is called to this, the usual explanation is, that the fault occurred before that upper group was deposited. This assertion is not so easily disposed of, but I consider that in the cases before us it is in a great measure disposed of: it may, I think, be held as impossible that disturbance of such magnitude as is implied by a fault of several thousand feet throw could take place between two groups of a stratified series, and not produce far greater effects of discordance than have as yet been observed between any groups of the Gondwána series. I do not forget that I have myself illustrated the compatibility of complete apparent conformity with synchronous great disturbance in the immediate vicinity (Manual, pp. 550-51); but that case rather enforces than invalidates the remarks I have just made: if the apparent discrepancy to which I have called attention were susceptible of an analogous interpretation, the notice of the feature as a simple fault would be none the less misleading. I would again invite my colleagues to a more critical attention to their 'faults': an erroneous fault within the stratified series may only lead to mistakes in calculating the position of any particular bed; but a mistake as to the nature of a main boundary leads us altogether astray in judging of the original conditions of the formation, the discovery of which is a principal object of our study. Thus, for this Gondwána formation, it is generally supposed to be in the main of subaerial origin, by rain and rivers, and presumably accumulated upon an area of subaerial erosion; yet the ever ready introduction of faults, pure and simple, at the limits of the basins, leaves this supposition out of sight.

KATTYWAR: *Mr. Fedden.*

In Kattywar, which belongs to the peninsular area, on the southern confines of the Arvali metamorphic region, Mr. Fedden completed the survey of some 1,900 square miles (sheets 24, 25, and 36) in continuation to the south of his previous season's work, besides making some preliminary traverses of adjoining ground. With the exception of a small inlier of Upper Gondwána (jurassic) rocks of the Umia horizon near Mewása, and very local outcrops of a sandstone locally underlying the trap, but containing trappean débris, the whole area is occupied by the great eruptive formation. It is mostly stratified, having a slight inclination to the south, but huge dykes traverse it in various directions, forming prominent ridges across the low undulating country. Terraces of the marine miliolitic limestone occur locally halfway up the sides of these ridges. The marble of local repute as Gondal marble is only an irregular sparry vein in the trap, not more than 2½ feet wide; it occurs at Khirsára and Sajriáli, 15 miles north-west of Dhoráji. A cursory visit was made to the famous Junagarh hills, the volcano-like construction of which was early noticed, but which were said to be in part formed of gneissic or granitic rocks. The isolated central hill forming the sacred peak of Girnár is a mass of thoroughly crystalline rock, a granular compound of a clear plagioclase

felspar and a dark-green mineral principally, if not all, biotite, and it seems, indeed, to be the core of a volcanic focus. The annular ridge surrounding Girnár, outside a deep intervening valley, is largely made up of trachytic dykes and bedded basaltic masses with a quaquaversal slope.

RAJPUTANA: *Mr. Hacket.*

In Rajputana Mr. Hacket added a very large area (more than 10,000 square miles) to his previous survey of the Arvali region, extending to the south-west as far as Erinpura. The scattered position of the outcrops in a wide-spread waste of sand makes such a result possible. As soon as the area to the east of the range is filled in, up to the Vindhyan scarp near Búndi, as Mr. Hacket hopes to accomplish during the present field season, a connected account of this portion of the region, up to Delhi, can be published.

The Vindhyan strata were found to cover a large area to north and east of Jodhpur. Their most north-easterly outcrop is at Khátu, 80 miles north-by-east from Sojat. They everywhere rest flatly upon the old rocks—the gneiss, the Raiálo schists, the Maláni felsites, or the Alwar quartzites. There is generally a thin band of fine quartz conglomerate, or of green shales, quite unaltered, at the base, overlaid by pale fine sandstone like the Kaimur rock, to which succeeds a red rock like the Bhánrer sandstone. The whole varies in thickness from 100 feet at Sojat to 350 feet at Khátu. There is sometimes a conglomerate between the two types of sandstone. Cherty calcareous beds are associated with the red sandstone at top, thus connecting this rock with an overlying limestone that covers large areas; it is locally 200 feet in thickness.

A very peculiar boulder formation is described as occurring on and about the Vindhyans, especially the limestone, yet not belonging to them. The blocks, up to 3 feet in diameter, are thoroughly water-worn, formed exclusively, so far as observed, of the Álwar quartzites. They lie loosely, without any matrix, in banks sometimes more than 100 feet thick.

The felsitic eruptive rocks described by Mr. Blanford as the Maláni beds, south of Jodhpur, are considered by Mr. Hacket to belong to the Raiálo horizon, as he found typical beds of that rock associated with the schists north of Dewair, in the centre of the Arvali range.

In the *Extra-Peninsular area* there were two survey parties at work in the cold season of 1878-79; and in the summer of 1879 two were engaged in the high Himalayas.

SUB-HIMALAYA: *Mr. Theobald.*

With the new maps of Kumaun Mr. Theobald surveyed, or at least explored, the belt of tertiary rocks at the base of the mountains between the Ganges and the Káli, in continuation of the work done several years previously to the west of the Ganges. Since these lower hills have been so extensively taken up for forest reserves they have become more inaccessible than ever, the temporary villages and the paths connected with them having disappeared.

The Siwaliks of this region (if indeed the strata of these flanking ridges include true Siwaliks, as Mr. Theobald seems to think) still maintain their character as unfossiliferous, no success having rewarded the search of so

experienced a collector. Other results, too, are wanting; the so far unique occurrence of eruptive rock in the tertiary sandstones at the Gola river (*see* Manual, p. 543) remains undescribed. After several consecutive seasons' work upon these sub-Himalayan rocks, Mr. Theobald has now seen more of them than any one else, and he should be in a position to throw some light upon their structure and history. There is no lack of independent speculation in the several progress reports sent in, but there is a too conspicuous want of critical observation, whether in support of the several conflicting views put forward by himself at different times, or in refutation of the interpretations already published by others. After the present season's work, however, we must place on record the result of his more matured study.

SALT-RANGE: *Mr. Wynne.*

In the past field season, or in part of it,—for he also made a reconnaissance of the ground far to the north between Kohat and Thal, on the Kuram,—Mr. Wynne accomplished the survey of the western extension of the Salt-range, from the Indus to the outskirts of the Sulimán range, beyond Shekh Budín. Following the great curves of the range, its length is about 100 miles, and considering the great intricacies of the sections, and the peculiar interest of many features of the ground, it will be readily understood that so rapid a survey cannot be very searching, much less exhaustive; but Mr. Wynne's map and description will form a thorough guide to future explorers, the leading features being no doubt pourtrayed with sufficient accuracy. Although the rock-salt, which gives its name to the Salt-range, extends a very short way west of the Indus, all the main structural characters of the western extension correspond with those of the cis-Indus Salt-range, with which Mr. Wynne is so familiar; indeed, without this knowledge the work could not have been accomplished. A principal variation found in this new ground is the expansion of the boulder zone, which near the Indus is the only rock between the Productus-limestone and the Salt-marl. At the south-west end of the Khasor ridge the purple sandstone is again in force, but with an intervening band of red clays, gypsum and dolomite, which alternate with the boulder beds at top. These middle beds are unlike those of similar composition in the saline series, below the purple sandstone, although their general composition would seem to connect them with those lower deposits of the Salt-range series. Mr. Wynne, however, suggests that they may represent the *Obolus* beds, which in the east Salt-range rest on the purple sandstone. Although nearly suppressed in the Maidán-Chicháli part of the range, the Ceratite and Productus-limestone groups are again exposed in force in the Khasor ridge, with very much the same characters as in the western portion of the Salt-range proper.

The jurassic series becomes more developed to the west of the Indus, and a well-defined distinction takes place between an upper calcareous marine zone and a lower one of sandy argillaceous deposits with plant-remains. Mr. Wynne calls attention to the contrast presented in this respect by the jurassic series here and in Rajputana, where the terrestrial (Gondwána) characters occur in the lower division, below the marine limestones, and the series as seen in Cutch, where these characters are found in the upper beds (the Umia zone) above the purely marine deposits.

A cretaceous zone seems to be the least defined of any in the trans-Indus series: while the original representative of a neocomian band is described as inseparable from the jurassic deposits, an overlying sandstone of the Chichâli section, at first conjectured to be possibly cretaceous, is described as apparently representative of a rock elsewhere shown to be post-eocene. The treatment of this horizon of the sections, the base of the tertiary series, is perhaps the least conclusive part of Mr. Wynne's work. Altogether his memoir will in this respect prove highly suggestive to future explorers.

By his trip through the very unfrequented ground between Kohât and Thal, of which an account is published in the Records for the year, Mr. Wynne was able to complete an unfinished border of the map and description previously given (Records, 1877) of a large area of the north-west Punjab.

SALT RANGE: *Dr. Waagen.*

In the introductory sketch to his description of the Salt-range fossils, in the Palæontologia Indica, Ser. XIII, fasc. 1, Dr. Waagen proposes a very important change in the grouping of the lower deposits of that area. Since the discovery of an *Obolus*, by Mr. Wynne, in one of the local groups of the series, represented as separated from the overlying Productus-limestone by two intervening groups in which no fossils had been found, although all do not occur together in any one section, it had been received as probable or possible that the Salt-range might contain a more or less partial representation of the palæozoic series, between the silurian, as represented by the *Obolus* beds, and the carboniferous represented by the Productus-limestone. Dr. Waagen now proposes to place all the four groups in one connected series, which he calls the Productus-limestone series. Such an arrangement would, of course, be impossible under any literal sense of the terms silurian and carboniferous, as previously applied to the separate groups. It is easy to imagine how the *Obolus* may be disposed of; Dr. Waagen's description of the fossils has not yet got so far; but he has not failed to indicate (*l. c.*, pp. 7 and 8) that he considers the deposits to be in succession laterally transitional and vertically associated so as to be inseparable.

Dr. Waagen has contributed to the November number of the Records an interesting suggestion regarding the older rocks of the Hazára region. It is based upon some fossils sent to him by the Geological Society of London for description in connexion with the Salt-range fossils. Among them were some in a black slate; they were labelled 'Punjab'; and there is some presumption that they may have come from the Attock slate group, which has as yet yielded no fossils to our search, but which has been provisionally ranked as silurian, partly from an equally uncertain conjecture (*see* Manual, p. 500, note) regarding some fossils found beyond Peshâwar. Dr. Waagen's fossils are of a well marked carboniferous type, and he points out that this age for the Attock slates would at least help to clear up some very puzzling features in the geology of Hazára.

LADÁK: *Mr. Lydekker.*

Mr. Lydekker explored a large area of Ladák to the east of his previous observations, and several points of interest have been determined. The gneiss of the Ladák axis, or Kailas range as Mr. Lydekker now calls it (in the Manual local names were preferred until we should know more about what we were discussing), was understood from Dr.

Stoliczka's description to be chiefly, if not altogether, formed of altered palæozoic rocks. Mr. Lydekker now shows that the gneissic silurians only occur locally, and that the principal mass must correspond to the 'central' gneiss (or Cambrian gneiss of Mr. Lydekker's previous papers, the identity of which with the 'central' gneiss may perhaps be doubted). The conformity and transition from one to the other is everywhere apparent. The metamorphics of Rupshu are, however, all represented as converted silurians. Thus we should still have to find the gneiss that yielded the blocks in the silurian slates of Pángi, and to explain the sharp unconformity of upper silurian strata on granite and gneiss in Hangrang. (Records, XII, 61.)

A special interest has been noted (Manual, p. 643) as attaching to the great trough of tertiary rocks found along the course of the Indus at the southern base of the gneissic range in Ladák, and crossing obliquely, with the great river, to the north side of this gneiss at a point south of the Pangur lake. Mr. Lydekker now shows from good sections that at several points of the boundaries, both with the oldest gneiss on the north and with the carboniferous rocks on the south, the natural original junction is exposed; and this is quite enough to rule the case, though at other points slipping may have been superadded. In several instances the bottom conglomerates of this eocene formation were even observed to show a relation of distribution with reference to the actual gorges of the gneissic range. We may thus henceforth dismiss from our speculations any thought of a former direct connexion of these central Himalayan eocenes with those at the base of the mountains in India, although the similarity of the deposits is so striking. Supposing that the formations of the Zánskár and Kárakoram basins were once continuous across the position of the Ladák axis, it would thus also be proven that a pre-eocene Himalayan elevation took place equal at least to the total thickness of the present sedimentary series from the base of the old gneiss to the top of the cretaceous; for only the unaltered portion of that series this would amount to 16,000 feet, according to Stoliczka's estimate. What the actual elevation of the mountains adjoining the eocene gulph may have been would, of course, depend on how far erosion had kept pace with elevation. The time required for such an erosion must be very great.

Upon the very interesting question of the amount of contortion that accompanied that great pre-eocene elevation, Mr. Lydekker seems to be slightly at variance with his facts, or at least his particular facts, as he duly observes, do not support the opinion he bases upon more general observation. He considers that the contortion of the older rocks took place in great part before that of the tertiaries, because the former exhibit puckerings and crumplings not found in the latter; but in the only contact section given that is not one of original abutting deposition, in the inlier at Miru, the carboniferous and eocene strata are nearly vertical in parallel superposition, so the older must have been flat at the time of deposition of the newer. It is certain that much compression and some crumpling must have attended the depression of the great sedimentary series, when its lower members were converted into gneiss; but it seems to me still an open question whether the great contortions which we now look upon as the special Himalayan disturbance, may not be post-eocene, though, of course, their

lines were determined by the great preceding act of general elevation. (*See* Manual, p. 634.)

Mr. Lydekker observes that the extensive exhibition of irruptive rocks connected with the tertiary series is not continuous throughout, and that the masses to the east are different in composition, or at least in texture, from those at the north-western end of the basin. This latter fact may be due to metamorphism accompanying the greater compression in this position, and which has equally affected the tertiary deposits.

NITI: *Mr. Griesbach.*

Mr. Griesbach has accomplished a very successful season's work in the higher Himalaya of Kumaun and Hundes. Compared to Ladák this is a happy hunting ground for the geologist, the rocks being well stocked with fossils, of which a good series has been brought in. Despite the distress of climate and great elevations, Mr. Griesbach has succeeded in mapping the snowy range between the Niti and Milam passes. He is still engaged in working up his materials, and the result cannot fail to be most interesting.

Mr. Blanford was engaged at office during the whole field season, at first for the completion of the Manual and afterwards to prepare his memoir on Western Sind, which had been postponed for some time.

Nothing special occurred to take me from Calcutta, and unless for some urgent duty of short duration, my absence would not be compatible with the steady progress of our work.

Publications.—Mr. Wynne's geology of the Salt-range was at last issued early in the year, having lain some fourteen months in type waiting for the colour-printing of the map. It forms itself Vol. XIV of the Memoirs. Mr. Foote's memoir (Vol. XVI, pt. I.) on the geology of the eastern coast from latitude 15° to the Kistna was issued in August. Mr. Blanford's geology of Western Sind was issued in December, forming Vol. XVII, pt. I, of the Memoirs. When the work admits of it, memoirs on adjoining areas, or relating to the same geological region, are brought into the same volume; thus, Vol. XV will be completed by Mr. Griesbach's memoir on the Ramkola coal-fields, now in the press: Vol. XVI will include Mr. King's memoirs on the east coast in Nellore and in the Godavari district, now preparing for publication; and Vol. XVII will be completed by Mr. Wynne's geology of the Salt-range trans-Indus, now at press.

The Records for 1879 contains 22 papers of various interest, with 11 maps and plates. Two of the articles are by contributors not attached to the Survey: that on Hangrang and Spiti by Colonel McMahon, and that on the old mines at Joga on the Narbada by Mr. G. T. Nicholls of the Civil Service.

Four parts of the Palæontologia Indica were issued during 1879: one by Dr. Feistmantel on the Flora of the Gondwána outliers on the Madras Coast (16 plates), and another by the same author on the Flora of the Talchir-Karharbari beds (27 plates); one by Mr. Lydekker on the Reptilia and Batrachia of the Indian pretertiary formations (6 plates); and the first part of the Salt-range fossils by Dr. Waagen (6 plates). An interruption was occasioned in the publication of Dr. Waagen's work by his receiving in the middle of the year the considerable collection of fossils made in the preceding field-season by Mr. Wynne in

the trans-Indus Salt-range. These had to be cleaned out and arranged with the previous collections before the work of description could proceed. I have already received plates and text in continuation of the work, including some of the specimens sent during the year.

I have great satisfaction in announcing that the description of the Sind fossil corals so generously undertaken for the Palæontologia Indica by Professor Martin Duncan, F.R.S., is very nearly completed. This is the fourth instance of distinguished palæontologists in England giving valuable assistance to the Geological Survey of India by the description of important groups of fossils.

I took an early opportunity, in the annual report for 1877 (Records, Vol. XI, p. 12, 1878), to state the principle of liberty and distributed responsibility under which I proposed to conduct the publications of the Geological Survey, and to explain how the conditions of our work in this country—the great distances to be accounted for and the peculiar difficulties of locomotion—made some such rule necessary to the full performance of our duties to the public. The evident drawback to such practice is the publication of crude work, in which even the competent reader (without any knowledge of the ground) can perceive that more intelligent observation might have given a very different account of the sections. To obviate this objection, the only alternative would be to withhold work from publication until it could be revised in the field by a more thorough observer. Unfortunately, owing to the great scarcity of really accomplished observers, and under the circumstances already noted, this would mean a quite indefinite postponement, and a stoppage of other work. Such had formerly been the practice: in view of further corrections the description of the Rájmahál hills had been withheld for fifteen years, and is at last in quite an unimportant degree better than it would have been at the first; and this is by no means an isolated case. Now, our principal duty is to the greater public, to furnish an intelligible map and description of areas hitherto geologically blank; and our least finished work does that, however imperfectly. The claim of the very select public of competent geologists—that all our work should be up to the best standard of the day—is incompatible with that prior claim, and with the conditions of the situation, subjective, and objective. The points where we fail in this respect do not much affect the value of the work as a guide to the ground. Of course every advice and suggestion is given in each case, so far as can be made from careful perusal of the work in manuscript, but the least intelligent workman is often the last to take advice, and the compelling reasons are mostly such as could only be worked out on the ground. I see no compromise but the one I adopted, and to which I adhere. The risk it obviously implies—the exposure of faulty work—falls upon our own heads. The minor evils it involves are no greater than those it removes, and the smart of public criticism is more wholesome than the heart-burning of official suppression. Correction is, however, seldom more convincing than advice, and in the endeavour to avoid it over-sensitive or under-ballasted writers even run into a worse predicament than that they would escape from. Thus the ball is kept up; the question of official suppression comes round again; as it is impossible that our publications can be made the vehicle of querulous rejoinders. Appeal is then made to non-official censors. Kindly editors of independent journals, quite ignorant of the merits of the case, and too busy to examine it very critically, act

upon the too plausible assumption that an eager protest against superior authority is probably well founded, and so they publish communications which their better judgment might lead them to decline, if only for the sake of the writer himself. I regret that an illustration of this difficulty has occurred during the past year.

Museum.—The various collections are in good working order. Two small popular guide books were prepared; one by Mr. Lydekker for our fine series of tertiary vertebrates, and one by Mr. Mallet for the minerals; they are sold for mere cost price at the door, and have met with some demand. Mr. Fedden is now engaged in rearranging the meteorites, amalgamating the Asiatic Society's specimens with the larger collection made by the Survey. Mr. Theobald has prepared a brief account of meteoric phenomena to be prefixed as a popular guide to the new catalogue.

Several small collections of rocks, minerals, and fossils have been forwarded to local Museums and Colleges.

Library.—The number of volumes and parts of volumes registered as received during 1879 was 1,283; being 604 by presentation, and 679 by purchase. Arrangements are in progress for the printing of the catalogue.

Personnel.—Mr. Ball was absent on furlough for the whole year. Mr. Foote left for two years' furlough on the 13th May. Mr. Mallet took 15 months' leave, on medical certificate, on 25th July. Mr. Blanford took 15 months' furlough from 23rd August. Mr. Hughes returned from furlough on the 15th October, and has taken up work in the South Rewah Gondwána basin on the west, from Katni.

I was absent on privilege leave from 26th July to 25th October.

Mr. Richard D. Oldham was appointed by the Secretary of State as an Assistant in the Survey, and joined his post on the 17th of December. He has taken up work with Mr. King in the Godavari valley. In addition to the high proficiency in geological studies evinced by Mr. Oldham at college and afterwards by independent work, we have the pleasure to welcome him as the son of the founder of our Survey and its successful director for a period of 25 years.

Apprentices Kishen Singh and Hira Lall having served their five years of probation with sufficient credit, and having acquired a serviceable knowledge of rocks and minerals, they received, on my recommendation, permanent promotion as sub-assistants. They have been in turn usefully employed in the Office and Museum in the place of the late Assistant Curator, and this post has been in consequence dispensed with. In turns they take the field with one or other of the geologists. It is still, however, very doubtful if they can ever prove competent for independent field-work. Geologist's work may not demand high mental powers, but it inevitably requires some originality of thought in dealing with observation and induction, that peculiarly modern turn of mind to which we owe the present development of natural science, the very quality which more than any other makes the western man different from the eastern. There is little or no gradation of work in geological surveying: to observe and interpret is required from the beginning; and the observation does not consist in measurements, or any kind of manual performance, but virtually to put a life into stones, and to trace the history of that life. Unless this is done with some approach to the standard of modern knowledge the work is not worth paying for.

CALCUTTA,
January 1880.

H. B. MEDLICOTT,
Supdt. of the Geological Survey of India.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1879.

BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Sciences.
BOMBAY.—Bombay Branch of the Royal Asiatic Society.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Naturalists' Society.
BRUSSELS.—Geographical Society of Belgium.
,, Geological Society of Belgium.
,, Royal Academy of Belgium.
CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Meteorological Survey.
,, Trustees, Indian Museum.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CAPE TOWN.—Ministerial Department.
CHRISTIANA.—University of Christiana
COPENHAGEN.—Royal Danish Academy.
DRESDEN.—The Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
,, Royal Irish Academy.
EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Glasgow University.
LAUSANNE.—Vandois Society of Natural Science.
LIVERPOOL.—Geological Society of Liverpool.
,, Literary and Philosophical Society.
LONDON.—British Museum.
,, Geological Society.
,, Iron and Steel Institute.
,, Linnean Society.
,, Museum of Practical Geology.
,, Royal Asiatic Society.
,, Royal Geographical Society.
,, Royal Institution of Greal Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
LYONS.—Museum of Natural History.
MADRID.—Geographical Society of Madrid.
MANCHESTER.—Geological Society.

MELBOURNE.—Mining Department, Victoria.
,, Royal Society of Victoria.
MOSCOW.—Imperial Academy of Naturalists.
MUNICH.—Royal Bavarian Academy of Sciences.
NEUCHATEL.—Society of Natural Sciences.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
,, Editors of the American Journal of Science.
PARIS.—Geological Society of France.
,, Mining Department.
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
PISA.—Society of Natural Science, Tuscany.
ROME.—Geological Commission of Italy.
,, Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SALEM, MASS.—American Association for the Advancement of Science.
SINGAPORE.—Straits Branch of the Royal Asiatic Society.
STOCKHOLM.—Geological Survey of Sweden.
ST. PETERSBURG.—Imperial Academy of Sciences.
SYDNEY.—Royal Society of New South Wales.
TASMANIA.—Royal Society.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VIENNA.—Imperial Academy of Sciences.
,, Imperial Geological Institute.
WASHINGTON.—Department of Agriculture, U. S. A.
,, Department of the Interior.
,, Smithsonian Institute.
,, United States Geological and Geographical Survey.
,, U. S. Geological Exploration of the 40th Parallel.
,, Geological Survey of New Zealand.
,, New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
,, German Naturalists' Society.

Governments of Bengal, Madras, North-West Provinces, and the Punjab; Chief Commissioners of Assam, British Burmah, Central Provinces, and Mysore; Superintendents of the Marine and Great Trigonometrical Surveys; India Office, London; Foreign, and Home, Revenue and Agriculture Departments; and the Resident, Hyderabad.

January 1880.

ADDITIONAL NOTES ON THE GEOLOGY OF THE UPPER GODAVARI BASIN IN THE NEIGHBOURHOOD OF SIRONCHA, *by* WILLIAM KING, B.A., *Deputy Superintendent, Geological Survey of India.*[1]

The last paper[2] written on the geology of this region by my colleague Mr. T. W. H. Hughes, the result, as it was, of later and more extended surveys, placed the relations of the Gondwána strata of this part of the Godavari and Pranhita area in so different a light in some respects to what I had anticipated in my paper[3] of the previous year that it became necessary to revisit the ground over which I had already made a cursory tour with Mr. Hughes.

The result has been to a certain extent satisfactory: a more detailed survey of the rocks has been effected, and some clearer insight obtained of the relations of the different groups of strata; but little additional evidence has been secured as to the conditions of the horizon between the upper and lower divisions of the Gondwána system than what we have ever had in this at first very promising region for the solution of that problem. There is no doubt, however, that we have here near Sironcha two great divisions of the Gondwánas, namely, the Kámthis and an upper series which we have gradually, through Mr. Hughes' researches, come to class as the Kota-Maleris, though I was myself inclined at first to introduce an intermediate group, the Sironcha sandstones, considering it representative of my Golapilli sandstones in the lower Godavari districts.

The main question, and that on which nearly all the others hang, is, as to whether the sandstones of Sironcha town are really of the upper or lower Gondwánas; but unfortunately, after all my endeavours, I have not been able to find fossils or sections which shall absolutely settle this point, though there is plenty of negative evidence on both sides of the question. I should naturally try to employ this negative evidence in favor of my own original view of their relations, but the balance of evidence given by Mr. Hughes seems, on the whole, to be more in favor of a lower Gondwána age for these beds.

The late Superintendent (Dr. Oldham) and Mr. W. T. Blanford are, besides myself, the only members of the Survey who have examined these puzzling beds, and Blanford had already inferred that they are Kámthis. His opinion had naturally great weight with me; but knowing that he had not spent much time over that locality, and that I had already been able to eliminate the upper Gondwánas from his general area of Kámthis at Ellore in the lower Godavari district, while I had up here the remarkable section at Kaleswar, the new facies of the rocks themselves, and the find of plant remains at Anáram, I was led to surmise that there were representatives here also of the lower Godavari rocks. Hughes' paper threw considerable doubt over this suggested correlation, but his

[1] The descriptions in this paper can in great part be followed with the aid of the small map annexed to Mr. Hughes' paper in Vol. XI, Part I, of the Records. A map of the completed survey will be published with Mr. King's full description in the Memoirs.

[2] Records, Vol. XI, Part 1, 1878.

[3] Records, Vol. X, Part 2, 1877.

boundary between the upper and lower Gondwánas did not satisfy me. I was again extremely puzzled by fresh features in the rocks at Kaleswar, and I find that the Aravi-Somnapali sandstones underlying the Angrezpali outlier of red clays are remarkably like those of Sironcha.

However, on carefully revising my last season's work, I really see no other way to a solution of the question than to yield the point that these sandstones of Sironcha town must be of lower Gondwána age, if not upper Kámthis, then possibly an independent group.

THE SANDSTONES OF SIRONCHA.

For convenience of discussion, it will be as well to write of these still as Sironcha sandstones. I have been led in great part, over and outside of the arguments put forward by Mr. Hughes, to look on these beds as of lower Gondwána age, through having found fossils (decided by Dr. Feistmantel to be preferably of Kámthi age) in rocks of Hughes' ground on the Wardha which from their lithological characters I had at once assumed as representatives of the Sironchas. This was near Porsa, and on a horizon corresponding to that of the Aravi-Somnapali sandstones.

I have unfortunately, with all my search, not been able to find any recognizable fossils at Sironcha, though there are some fragments of stalks on red shales bearing a faint resemblance to others in the Anáram beds. It likewise appears from the following note[1] of the Rev. Mr. Hislop that fossils of lower Gondwána age were once found at Sironcha. "In the sandstone at Sironcha, 6 miles further down the river Pranhita, there is an abundance of compressed stems identical with those at Silewáda: so that there can be no doubt that the argillaceous sandstone there is of the Damuda group. This sandstone of Sironcha is stated by Mr. Wall to underlie almost immediately the Kota limestone."

Looking on the 'Sironchas' as of lower Gondwána age, I can then place the boundary between them and the Kota-Maleris more definitely than was attempted by Hughes: in fact it must run very much where I always drew the line between the Sironcha sandstones and the Maleri clays, or rather the Kotas, for the remarkable feature about the Sironcha sandstones is that they (unlike the other Kámthi or lower Gondwána outcrops to the north-west of Sironcha) are not overlaid by Maleri clays, but by Kota limestones.

From (and including) Sironcha town to the Godavari river opposite Kaleswar there is a tolerably continuous outcrop of sandstones in the left bank of the Pranhita, in which there is not a break allowing of such a boundary as that suggested by Hughes in his map being continued to the Sironcha side of the river. The Sironchas must be considered as at least extending from the north-east suburb of the town to Nagrum opposite Kaleswar. If ever it become necessary to distinguish the Sironchas as upper Kámthis or as an independent group, then their lower boundary must be drawn at Kaleswar, though not at the section on which Hughes and I ultimately agreed that there was only a resemblance of unconformity.

[1] Pro. Geol. Soc., London, 20th November 1861, Vol. XVIII, p. 36.

I have been able this year to trace decisively the beds of Sironcha town across the Pranhita into the rising ground culminating in the hill-station above Arjunguta. We had, I think, always supposed this to be the case, and the hill-station beds had ever seemed to me of a true Kámthi facies, while the ascertained continuity of strata so far carries these beds nearer to the Anáram strata with their upper Gondwána plant remains. The hill-station beds are brown and ferruginous with a decided Kámthi look, and are in part very hard and vitreous, having thus a much older appearance than the Sironchas; however, I actually found unmistakeable Sironcha beds merging into these hard vitreous beds; and so there is no doubt at all, in my mind, that the Arjunguta bed and those of Sironcha are the same; while the former have the Kámthi facies. The Arjunguta hill-station is at the west-south-west end of a line of faults which may be said to limit in part the north-westerly extension of the Sironcha strata, these being also cut off to the south-east, after a length of some 15 miles, by another more or less east-and-west fault near Ardium on the left bank of the Godavari.

To the north of the Arjunguta hill-station are the oft-noted Anáram beds which yielded the plant remains *Palissya conferta* and *Chirolepis münsteri*, and which I had concluded were overlying the Sironcha beds in natural sequence. The sections and exposures of rock in this part of the country are not continuous, as they are covered up in the most disappointing way by alluvium, and there is the fault just mentioned; still a certain connexion of the Sironcha beds with others in the Kota-Maleri field is apparent, which will always, until fossil evidence be found, cast a shadow of doubt over the grouping and mapping of this series.

As it happens, the Anáram beds are not traceable in the Arjunguta outcrop, but they may be followed down by the right bank of the Pranhita to a point east-north-east of the hill-station, where the outcrop ceases suddenly, there being nothing hence for a mile or so but the high alluvial bank of the river, which bays inland for some distance, lapping round the slopes of the Arjunguta high ground. Not only is there this abrupt ending of the strata, but, after pursuing an even course with a lie of 20° to 30° to the east-north-east, they suddenly show signs of a sharp bend to the south-south-east, with rough slickensides and much silicious and ferruginous infiltration. Nearly all safe signs of lamination and bedding are obliterated in the strong silicious infiltrations which strike irregularly in a general east-north-east to west-south-west run and nearly vertical dip. From this point to the hill-station there is a decided hard wall or ridge of beds much impregnated with silicious and ferruginous matter in the same irregular strips and seams; Anáram pebble beds, purple shales, clays, and sands forming this wall and lying to the north of it.

An important feature about the Anáram locality is, that in going west-south-west from the village, one passes over softish red lilac and buff sands, pebble beds, shales, clays, &c., having a tolerably regular north-east lie; but after about half a mile the beds become troubled, rather flaggy, hard, and more and more ferruginous, when it becomes gradually apparent that one must now be on Kámthis. Such a succession, in descending order, may be found up any of the nalas to the north-west of Anáram as far as Yedlabundun; and thus there seems

little doubt that the Anáram strata are overlying Kámthis, which, though this is partially concealed and interrupted by the fault, are apparently continued in the Arjunguta hill and at Sironcha. No red Maleri clays come in between the Anáram strata and the Kámthis of Linganapeta, but true red clays occur near Isnai, some 5 or 6 miles west-north-west, serially at a much lower horizon than the Anáram beds.

At Yedlabundun everything is covered up for some miles along the valley of the tributary stream, so that neither the Anáram nor the Linganapeta beds are traceable with any certainty to the north-west, though the Anáram beds seem to be continued in the sandstone belt underlying the great zone of limestones striking away to Mulkalapeta, which, as will be seen further on, I take to be the same as the Kota band.

Thus far, the points gained or advanced in this enquiry are—

First, that my so-called Sironcha sandstones are of lower Gondwána age and probably belong to the Kámthi group. They are extremely like those of Aravi-Somnapali, which are on a horizon corresponding to that of the beds near Porsa, which Mr. Hughes had already determined as Kámthis, a conclusion verified by the fossils I afterwards found in them.

Second, that the Anáram plant shales are locally bottom beds resting on Kámthis, and lower in the Kota-Maleri group than the Kota zone of limestones.

THE KOTA-MALERI GROUP.

The most definite and recognizable strata in the Kota-Maleri series are the limestone bands. Hitherto, we have been under the impression that there might be only one of these, that of Kota itself, of which the outcrop at Itial (on the Jangaon river) was a portion. I have, this season, been at the trouble of looking up all the outcrops of these rocks, and there is now no doubt at all that there are at least three bands or zones; still the evidence is not quite clear as to the course of the Kota outcrop, that is, it is not continuous over the most important parts of the field. Indeed, the whole limestone sub-division, or what I have previously called the Kota group, is so much broken and interrupted near Sironcha that it will perhaps be better to treat of it separately, as it occurs in two areas, to the north-west and to the south-east of that town.

The Pranhita area.

The Kota Band (No. 2).—To the north-west of Sironcha there are, first of all, the historic beds of Kota, a mere isolated outcrop in the left bank of the Pranhita. It is to all appearance the same band as that of Tondala to the east of Sironcha, and it appears again to the north-west as the great band, with similar fish scales, at Katapur, whence it stretches away up to near the bank of the Jangaon river at Parwatipet. The line of the Arjunguta fault may strike across between the Kota and Tondala outcrops, so that it is possible they may not be of the same band, though I think they are, being merely stopped for a short distance, but there seems no reason to doubt that the Kota and Katapur outcrops are of one and the same band.

The Bagarami Band (*No.* 3).—Towards the Jangaon river and about a mile and half eastward of Parwatipet are some further exposures of limestone in a still higher band, the highest in fact that we know of, but I was not able to detect it to the south-east, except, apparently, spot between Waddaguram and Somtum on the right bank of the Pranhita. This band may also possibly give a doubtful outcrop, noticed last year, as lying below the Chikiala scarps north of Sironcha. No fossils have been seen in this outcrop.

The Metapali Band (*No.* 1).—This occurs about 2 miles or less to the west of that of Parwatipet, and is thus lower in the series than the Kota band. It is strongest about Metapali, being there about a mile in width, with a very low dip, and thence it is traceable for a long distance to the south-east past Surarum, Katapali, and Busnai, and for 5 or 6 miles further in that direction. To the north-west I could not follow it satisfactorily, but it appears to run straight for Bibra, a short distance north of which are some outcrops of hard dark-colored limestones. So far this band has failed to yield any fossils. The lie of the beds is, however, so very low, often nearly flat, at its north-east end, that I am almost inclined to think that this band may be represented in the Itial outcrop lying much more to the west-north-west.

The limestones of Itial form, to all appearance, a completely isolated outlier of nearly flat or flat-rolling beds resting on red clays associated with a thick series of sandstones, which in their turn overlie the proper reptilian red clays of Maleri. They are thus for this part of the country the lowest true limestone band in the Kota-Maleri group, and certainly in this way they correspond to the Metapali band, which for its known length is also the lowest band, resting also on a sandstone belt overlying the reptilian clays. The Itial beds are fossiliferous, with lepidotus scales.

Between the thin limestone beds, and above and below them, are great thicknesses of rather soft, open textured variegated sandstones, sometimes having strong runs of buff, pink, lilac and white clay galls and rolled lumps, with which are intercalated thin bands of red and chocolate-colored clays. The limestones shade rapidly downwards into the sandstones by calcareous sands and clays, and intercalated with them also are thin seams of bright red clays. If I am right in my surmise that the Anáram beds are continued north-westward past Yedlabundun, then they lie between the Kota and Metapali bands. This places the *Palissya conferta* and *Chirolepis münsteri* of Anáram with the liassic fish of the limestone or Kota sub-division.

A remarkable feature about the stratigraphy of these limestone bands is, that they are not traceable to the north of the Jangaon river, though two of the sandstone belts associated with them and the red clays are continued on to the Wardha river. Of course this non-appearance of outcrops may be due to the very thick covering deposits of the Jangaon valley; but the probability is, I think, that they have thinned out, and that their flatter lie allowed of greater erosion, only one isolated patch of the lowest band being left.

The lie of the beds is generally very low, from 2° to 3°, though the outcrops are often broad and marked, giving an idea of great thickness. For instance, the most steady and fair outcrop of good massive limestone beds, in the Kota band

near Katapur, cannot be much less than 800 yards wide, which at an average dip of 5° would only give about 200 feet for the thickness. The limestone is usually a grey compact hard splintery rock, rather clayey or earthy, with many seams of white chert; in fact, it appears to have been originally a fine calcareous mud.

The limestone series comes suddenly or decidedly over the Maleri clays by the presence of distinct bands of limestone strata. I could not, however, ascertain in this Pranhita field that this upper member is fairly separable from the Maleri clays except by a sort of overlap, at either end of the field, of the sandstone below the Metapali-Itial band, and that the red clays have their distinctive rubbly calcareous sandstone, just as the upper member has its distinctive bands of limestone. I do not recollect a single instance of rubbly calcareous sandstones in the upper member; but there certainly is a shading of the calcareous elements throughout the group as from distinct river deposits to others of a more estuarine character.

The Metapali-Itial limestones overlie soft variegated sandstones with many thin intercalated beds of red, white, and greenish clays, and a band (or perhaps bands) of dark grey calcareous sandstone, massive and compact, putting on, on weathered surfaces, a guise of limestone so strongly that it must be hammered at to distinguish it from the true rock. Neither is it the rubbly calcareous rock of the red clays. It may be considered as a kind of passage rock deposited in the period of change in the character of the waters of the Kota-Maleri basin This calcareous grit is very constant in the sandstones below the Metapali band, all round (starting from the Itial end) by Rajaram, Sardapur, and Bamena, and so down to Kondampeta. It shows again in force, but somewhat sub-divided, in the thick series of sandstones underlying the Itial limestone and spreading out to the west-north-west up to the Jangaon river from Gungapur.

In following the limestone member to the south-eastward, the Metapali band seems to thin out, though the sandstones above and below it are in force to the tributary nala flowing down towards Yedlabundun. This thinning out may, however, only be apparent, for it is wonderful how these limestone bands are hid beneath the more recent deposits, the débris from the outcrops of the associated sandstone belts being enormously spread over the country.

At any rate, at or near Sironcha, the only band carrying the Kota-Maleris into the Godavari area is that of Tondala, which I take to be of the Kota band, and it is in very close proximity to the Sironcha sandstones.

The Godavari area.

The Kota-Maleris, or perhaps more properly the limestone or Kota member of the group, has been traced out in this direction with somewhat more detail, but there are awkward breaks in continuity of strike, and a very large area to the south of the Indrávati bend of the Godavari is either covered up by superficial deposits, or too shut up by jungle for close survey.

I carried the Tondala outcrop fairly down to Chitur, beyond which village there is no further trace of such rocks until within a couple of miles of

Assaralli; but these beds are shifted out of what would be the course of the band, and very possibly belong to the uppermost Bagaráni zone.

The Tondala outcrop is underlaid by the Sironcha sandstones as far as Chitur, where the latter also end abruptly at an east-west fault, and are succeeded in their strike by two fresh outcrops of limestone. The nearest of these to that of Assaralli is a rather broad and distinct one, running down to Ankissa. This is of the usual Kota stamp, and I take it as corresponding to that outcrop, though no fossils were found in it.

Some 3 miles further west a very strong and rather broad band of limestones occurs close to Ardium, and thence it is continued south-east to the left or north bank of the Godavari. There was no yield of fossils here, but this band must, I think, be looked on as answering to that of Metapali-Itial in the Pranhita area. The feature of this outcrop is, that it is unmistakably faulted against Sironchas, while it rests on sandstones, clays and shales of the Kota-Maleri type.

The great east-west or Indrávati reach of the Godavari presents a blank of new alluvial deposits, but on the right or opposite bank two broad spreads of fossiliferous limestone are again met with which must be continuations of those at Ankissa and Ardium.

The Assaralli outcrop could not be expected to appear, as it must have trended under the Chikiala sandstones of Woraguram. However, to the west of this village, there is a great show of strong beds, for about a mile in width, implying a thickness of 448 feet at least; and in a tumbled outcrop of these I found a fine skeleton of a fish and matted masses of scales. Here also are two thin seams of carbonaceous shale, an accompaniment which adds further to the identification of this as the Kota band. In the broad outcrop of thick-bedded limestones, I obtained a few specimens of fish and saw many others which could not, however, be chiselled from the huge blocks of hard splintery rock. This band could not be followed further south than Palmela owing to the covering gravels and sands.

Three miles further westward there is again a wide belt of limestones having its western edge near Lankalagada, in which a few more fish-remains were found. Here, again, the beds are faulted against sandstones forming the bank of the river, the north-north-east dipping strata being bent down to the southward at the Lankalagada end of the fault. The line of fault is not very clear, but it was more or less east and west, rather to the south of east. The limestones, like those of Ardium, overlie sandstones, which must be considered as of the Kota-Maleri group. The sandstones on the north side of the fault, and forming the bank of the river, are, I think, Kámthis.

This outcrop is traceable south as far as Sigampali, and beyond this only faint traces of limestone occur near Redipali and towards Ahilapuram, where the Kota-Maleri strata trend close on the Kámthis of the ridge south of the village; but there is no section showing the relation of the two groups.

In this southern portion of the field, there are no strata answering exactly to the Maleri member of the group, or the proper Red-clay sub-division; but

it is probable that there is a great thickening out of the sandstones below the Ardium-Lankalagada outcrop.

Certainly there are neither sandstones nor clays answering in any way to the Maleris between the Tondála-Chitur outcrop and the Sironcha beds, though such may have been thrown down by a north-west to south-east fault, else may be hidden under the Tondála beds and deposited against a steep face of Sironcha. I could see no trace of a fault along this line, or running from either end into the Maleri country or south-eastwards to Assaralli; hence it would seem as if a natural, though very abrupt, boundary were the simpler interpretation of this unusual association of the Upper and Lower Gondwánas.

But this is an association implying strong unconformity, such as might be expected to occur under the marked overlap pointed out by Mr. Hughes as existing between the Kota-Maleris and Kámthis.

The Ardium limestones overlie a set of sandstones which are very well displayed in the river bank going towards Aipeta. Proceeding up along the river bank, these thick-bedded sandstones are succeeded by a good thickness of variegated beds, and then by irregular bands of greenish-white clays, calcareous sandy clays and shales, and rough rubbly marly-looking bands with recurrent white and light-colored arenaceous beds and other harder seams of sandstone, all having rather a calcareous constitution; and then there are traces of thin chocolate clays coming in towards the top and underneath the limestones. There are also beds of about a foot thick of calcareous grits with small lumps of greenish and red clays.

These are very much the style of rocks overlying the Kota limestones, and, indeed, such as appear here and there, only much less freely exposed, associated above and below all the limestone outcrops; but there are no signs of the bright red-clay series.

Immediately north of the small hamlet of Madagam on the opposite bank of the river, there is a good outcrop of beds like those on the Ardium side; but their ends are faulted against a stronger outcrop of arenaceous beds immediately under the village, in a nearly east-west line. The beds on the north side are much seamed with nearly vertical east-west veins and strings of silicious constitution, the result being that the outcrop is more a series of hard ridges in this direction, giving an appearance of bedding, while close to the fault itself the ends of the strata are turned down to the northward with slickensided faces having a dip of 70°.

In the absence of fossils and any very decided lithological characters, it is, of course, impossible to say that the Madagam beds on the south side are really of a different group or series to those on the north side of the fault; but they certainly appeared to me to have more of a Kámthi facies, and to be the same as the beds further down the river side near Lankalagada.

I have already, in previous progress reports, given an account of the strata underlying the Lankalagada limestone, describing them as of the Kota-Maleri group. They are all sandstones with a few thin bands of red clay, and low down in them is a thin calcareous band showing scarcely a fair limestone flag. Now

that I have had an opportunity of examining the Maleri field more closely, I may say that these rocks remind me very much of those underlying the southern portion of the Matapali-Itial limestone band.

Thus far I can write of those southern beds, and the apparent absence or non-existence of any red-clay series; but as the country has not yielded to me any evidence as to the boundary, except that there must be one in the approximate line I have drawn south-eastward from Madapur, I cannot say that the Maleri clays may not be hidden by faulting, or along an old steep shore edge. There is no doubt that the country above this reach of the Godavari is a good deal cut up by dislocation, more generally in the east-west line, and there are indications of steep shore edges.

As bearing on this, however, it may be as well not to leave out of notice a very exceptional occurrence of red and green clays some miles further south, right in the centre of one of the most unfrequented parts of this largest jungle waste in the Nizam's dominions. About 13 miles south of Ahilapuram, while working over an immense succession of ferruginous sandstones which must be reckoned as Kámthis (though I have hitherto always strained at an upper Gondwána place for them, owing to their Sironcha facies) on the Konda-party stream I suddenly came on high banks of red clays with green and white seams and partings of the well-known Maleri type. I tried all I could to carry this outcrop into some sort of relation with the coarse-brown sandstones in the adjacent jungle, but without success; and I can only now record its occurrence, with the surmise that it is left there in the midst of Kámthi strata by faulting, or possibly as an outlying patch.

Before turning north again to discover more closely the further evidence which has been obtained of the red-clay series, it will be as well again to note the points which have been gained or advanced so far—

1. The Kota-Maleri group may be considered to consist of two members, an upper division characterized by having three well-marked limestone zones, two of which contain fish-remains having liassic affinities, and a lower division characterized by a strong development of red clays with remains of reptiles and fishes of triassic age. This marked difference of age of animal remains in what appears to be one group of a formation is now partly accounted for in the fact that the rocks containing one set are decidedly higher in the group than the rocks containing the other; and as there is still a certain amount of hesitation[1] exhibited by my colleagues in their writings on this single point, I may be excused for reiterating this important feature in the stratigraphy of the Kota-Maleris.

2. In the southern or Godavari area of the Kota-Maleris, the sandstones below the lowest band of limestones have thickened out enormously; and there is no known outcrop answering well to the Maleri clays.

[1] See Mr. Hughes' Rec. Geol. Survey of India, Vol. XI, Part 1, page 25, line 34, *et seq.*, W. T. Blanford, Palæontologia Indica, Ser. IV—2, page 20, line 32, *et seq.* I never considered that the Kota limestone is a band intercalated in the Maleris, though I did agree with Hughes that the two might be of the one group. Again, in the Manual of the Geology of India, page xxiv, line 9, *et seq.*

3. The lower Gondwánas of Sironcha town are succeeded directly by a limestone band of the upper division, either naturally, but abruptly, or less probably by a faulted boundary; but this would only be evidence of unconformity between the lower and upper Gondwánas and not, as I have hitherto supposed, of a break between the two members of the Kota-Maleris.

4. The Anáram sandstones with *Palissya conferta* and *Chirolepis münsteri*, are to all appearance on a horizon between the Kota and Metapali-Itial limestone zones.

One more point of evidence bearing on the relations of the limestone member has been obtained in the Angrezpali patch, which may traverse Mr. Hughes' surmise that the red clays there are on a higher horizon than those of Maleri: for I have found limestones of the Kota type lying just along the southern edge of this patch of clays, on the right bank of the Godavari to the east of Damarakunta, between Malarim and Gondapali. The association is, as usual, not at all clear owing to the covering alluvial deposits of the river; but there is no doubt of the limestone being there associated with sandstones overlying the red clays.

The Maleri Red Clays.

I took up these at the typical exposure on the Wardha river near Porsa, and so carried them southwards, without continuity, but to all appearance and by associated sandstones, towards the Jangaon valley, whence they are more easily followed into the proper Maleri field. The Porsa red-clays, however, run under, or to write more correctly, run close up to, and must eventually underlie, sandstones belonging to the belt above the Kota zone of limestones. There is no sign of, nor can there be any room for, the sandstones below that zone, or for the Itial band. There certainly seems to be at this end of the field evidence of a cessation of deposition over the northern frontier of the red-clay basin, which portion was, however, eventually covered up by the later belts of the Kota member (the third sandstone belt, that of Sarwai and Sarsal ridges). This, of course, is virtually only an overlap of these sandstones, not necessarily of the whole limestone sub-division; but there is further evidence yet to come of the possible overlap of the whole sub-division at the Anáram end of the field.

To the south of the Jangaon river, the red-clays show in all their decided outspread; a fair series, displayed more especially about Nambala, Komreli, and Achlapur, of south-eastward dipping red clay bands with intercalations of thin aronaceous beds, and more particularly many bands of grey rubbly calcareous sandstones with indured red, chocolate, and greenish lumps of clay. The reptilian remains must have come from beds in the Maleri field, and not from any higher bands of clay in the upper member, the drainage being all to eastward. The eastern edge of the clay basin runs from a little south of Nangaon past Gungapur, Wodala, Venkatapur, Kasnapali, and Nakalapali to Isnai tank, some 7 miles west-north-west of Anáram. Mr. Hughes, in his small map,[1] carries the western boundary of the clays rather more to the westward than I would have it, but there is certainly a section between Naneala and Rebni showing

[1] Rec., Vol. XI, pt. 1.

that the clays lap over and round brown sandstones and pebble beds (striking north-west to south-east) of unmistakable Kámthi type with ferruginous warts and fungoid segregations. Mr. Hughes' boundary does not run down as far as Isnai, but my having carried it so far is an important point as fetching the lower Gondwána boundary down more to the westward of Anáram with a less easy curve round the Kámthis of Linganapeta.

Along their eastern edge, the red clays suddenly become less persistent, and are succeeded by variegated sandstones with intercalated clay seams, and then by a thick series of thick-bedded sandstones which is perhaps most clearly developed in the fine cliffs, of 60 to 80 feet high, south of Gungapur, and this set of beds may be followed towards Naogaon, or south-eastwards past Akalapali, Kesapur, Sardapur, Bamena, and Kondampeta. The red clays undoubtedly now cease to be the feature, though thinner and thinner seams show as these Gungapur sandstones are followed up; but at the top of them and immediately under the limestones of Itial is a red clay band, next a thin band of limestone, then red clays again, and then the thick zone of limestones. The difficulty is—considering that we have never found any of the Maleri reptilian and fish remains *in situ*—to say from which bed these were derived. The calcareous, or rubbly calcareous sandstone, or even coarse white grit, usually attached to the specimens, would imply that they come from the bands of these rocks in the red clays, and that is at a horizon entirely lower than the Gungapur sandstones: I am also strongly inclined to consider that this is really the case.

From Venkatapur southwards, the Gungapur sandstones, or what I take to be the representatives of them, show above the middle the strong calcareous grit, simulating limestone, already referred to, and I think this seam may be traced down as far as Kondampeta at least; indeed it appeared to me that it runs down even as far south as the parallel of Isnai. West-south-west of Venkatapur, towards Naogaon, &c., I did not find the one calcareous band of grits so clear; there appeared to be more than one band.

The Gungapur sandstones pass along by Naogaon, forming one group with the thick bedded rocks of Aksapur, and I think, those of Chirákúnt, Belgaon, and Balánpur, from all of which Hughes obtained the fossils enumerated in his paper.

Hughes says (*l. c.*, p. 28) of these fossils and the localities—

"In the neighbourhood of Idlara there are the unmistakable red clays with lenticular layers of greyish green granular argillaceous sandstones, and sandstones with clay galls, of the Kota-Maleri group. Thence to the south as far as the range of hills capped by trap, there is no interruption to the series; and at a short distance up the north face of the range and about a mile and a half of Chirákúnt, soft, pale yellow, fossiliferous shales occur that yielded the few species of ferns, cycads, and conifers, &c." "The same plant (*Palissya conferta*) was discovered in 1872 by Mr. Fedden between Móhár and Balánpur, west of Jangaon, in sandstones which I have included as Kota-Maleris." The shales and sandstones near Naogaon (in which I last year discovered *Palissya jabalpurensis* and *Araucarites kachensis*) are also components of the group. They may be higher in the series than the Móhár Balánpur beds, their plant forms sug-

gesting this surmise. I cannot adduce any stratigraphical evidence that bears upon the relationship of the Naogaon and Móhár-Balánpur or Chirákúnt beds, for sections are of the most broken and uninstructive character throughout the whole of the valley of the Jangaon river.

I was not able to visit the Chirákúnt locality, but the whole stratigraphic features seemed to me to indicate that there might be a set of rocks, over the red clays, corresponding to the sandstones of Naogaon, for the lie of both sandstones and underlying red clays is very low or nearly flat over this part of the valley, and the fossils were obtained from a spot a short distance up the side of the hill range. The Móhár and Balanpur fossils were found in sandstones apparently above the red clays; and I have not the smallest doubt but that these rocks answer to those of Naogaon, Aksapur, &c., in fact they belong to the Gungapur sandstones, that is, are above the fossiliferous red clays. Hughes is right about their being in the Kota-Maleri group; but it is highly important that their horizon in this group should be known; and there is this fact certainly, that the Naogaon beds at any rate are Gungapurs, and that the Gungapurs are above the proper red clays.

Having so far made out a little more as to the horizon of the plant beds of the Jangaon valley, it would be a most important gain if they could be placed in accord with the Anáram beds to the south-east. I can, I think, carry the Gungapur sandstone zone down as far as Kondampeta, whence certainly it may have curved round to the east-south-east, and so form the Anáram strata too, thus lapping over the red clays of Isnai on to the Kámthis of Linganapeta. This seems a not untoward lie of the strata, and it is a very tempting position to place them in, as it would give a strong point in favor of the overlap indicated in the Wardha valley; but I cannot satisfy myself on this point. The several bands of sandstone and limestone above the red clays appeard to me to be all running south-east right at the Linganapeta ground. There is, however, a lower lie and a strike round more to the eastward in the rocks about a mile and a half or two miles north of the latter village, and the red clays spread out rather to the south-east of Isnai, so that there may really be a trend round towards Yedlabundun. In the meantime, I prefer to think that the limestone member of the Kota-Maleris does not thin out so easily near Isnai, and that the Anáram beds' position is between the Kota and Itial-Metapali band of limestones.

The point I would now suggest is, that we have here, at the Isnai end of the Maleri field, tolerably present in evidence that the red clays are being well overlapped by higher and higher strata of the limestone member between Isnai and Anáram.

For the whole field of Kota-Maleris, the various points gained or suggested may be summarized thus—

The series appears fairly separable into two groups, the Maleris and the Kotas, which have already been referred to in this paper as the Red-clay and Limestone members The Red-clay or Maleri sub-group is overlapped at its northern end, between the Jangaon and Wardha rivers, by an upper sandstone zone of the limestone or Kota sub-group; and even before the doubtful boundary between the sandstones of Sironcha and the Kota limestone is reached to the

southward the same clays are again overlapped by the Anáram strata: while they do not appear to be represented in the southern or Godavari portion of the field.

This separation by overlap accords in some measure with what is known of the animal remains found in either.

The position of the plant-remains is less clear, but that of the Naogaon and Anáram, and perhaps of the Balánpur fossils is above the red-clays, there being overlap in the Anáram case. The plant-shales are in sandstones which run with the red clays up the Jangaon valley, but this, the Gungapur band of arenaceous strata, does not appear to be represented on the Wardha river, the clays there being overlaid by strata to all appearance higher than the Kota zone of limestone; hence we may infer that the Gungapur beds are not co-extensive with the clay series at the northern end, while they overlap it at the other end of the field. On either view of the horizon of the Anáram plant-shales, either as a thinned-out end of the Gungapur beds, or as of the arenaceous zone between the Itial and Kota limestones, their position is still above the clays. I have endeavoured to explain the positions of the Chirákúnt shales as being also above the clays.

The great difficulty lies in saying where the Maleris are to be considered as ending, and where the Kotas begin. I am fairly at a loss in the proper Maleri field itself, for there are no known sections giving the relations of the two subdivisions. I think the Kotas must be considered as commencing with the Gungapur sandstones even though there be so many thin seams of red clay in that set of rocks as well as up into the limestone zones. The Gungapur beds are thick, and in their constitution they point, on the whole, to a kind of deposition totally different to that of the red clay series, after which a great change must have taken place in the drainage system of the country bordering the Maleri basin; while the successive overlapping of the succeeding deposits on the clays at the northern end of the field indicates a long period of unrepresented time during which the change in animal life might have taken place.

I would then only modify Mr. Hughes' latest classification of the upper Gondwánas so far as to break up his Kota-Maleris into two of the groups proposed in my original provisional list, which are themselves also modified, inasmuch as the Anáram beds are now ranged in the Kota group instead of with the Sironcha sandstones.

CHIKIALA SANDSTONES.

These were followed out to their bounds in this area, but without giving any more evidence as to their relations with the Kotas. However, until more is known of them, it will be better to leave my old correlation of them with the Tripati sandstones of the lower Godavari Upper Gondwánas as a very open question. In some respects they are even like the much newer and tertiary Rájáhmandri sandstones of that region. My arguments as to the age of the Balánpur beds will show that I do not think they are at all recognizable by position as Chikialas.

GEOLOGY OF LADÁK AND NEIGHBOURING DISTRICTS, BEING FOURTH NOTICE OF GEOLOGY OF KASHMÍR AND NEIGHBOURING TERRITORIES, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

(WITH A MAP).

INTRODUCTION.

The portion of the Himalaya geologically examined by myself during the past summer comprises the country on and adjoining the main road from Kashmír to Leh, a considerable portion of Drás, Zánskár, and Ladák; the regions about the Pangong Lake and Cháng-Chenmo, and a part of Rupsu and Kulu.

A considerable portion of this area has been already traversed by the late Dr. Stoliczka, and the serial position of most of the rock-groups occurring therein approximately determined.[1] Dr. Stoliczka's survey was, however, mainly confined to the high-roads, while my own embraces a large extent of the surrounding country. I am, therefore, able to present a fairly complete general map of the greater part of the districts in question, in place of the isolated rock-groups colored in by Dr. Stoliczka. My own more extended observations have also led to certain modifications of the views entertained by Dr. Stoliczka as to the relative ages of some of the rocks in these regions, but on the main I agree with the conclusions arrived at by our former colleague. I may also add that I am indebted to Dr. Stoliczka's notes for some of the boundaries shown on the map.

In my previous papers on the geology of the Kashmír Himalaya,[2] I have generally treated the subject in the manner of an itinerary; describing the different rocks as they occurred on my various routes. This method of treatment, however, would not be suitable to the present area, and I, therefore, propose to treat of each group of rocks by itself.

In geologically mapping an area which consists in the main of exceedingly lofty mountains and elevated valleys, it is of course impossible from the nature of the ground, to be always perfectly accurate in tracing continuously the boundaries of the various rock-groups; not unfrequently, therefore, in my map when such boundaries are far removed from the roads, they must be considered merely as more or less accurate approximations connecting the fixed points where the boundaries cross or approximate to the practicable roads, or accessible regions.

I shall divide my subject into four main headings, *viz.* (1), the older Palæozoics of Drás and Ladák, (2), the rocks north of Cháng-Chenmo, (3), the rocks of the Zánskár and Ladák basin, and (4), the rocks of Lahúl and Kulu, while in a fifth section I shall make some more general remarks on the relations of the rocks of the whole area.

I once again have to deplore the absence of any trace of fossils in the older Palæozoics of the region surveyed, which absence precludes any minute sub-

[1] Mem. Geol. Surv. India, Vol. V, pp. 182, 337. Scientific results of Second Yarkand Mission: Geology.

[2] Rec. Geol. Surv. India, Vols. IX, XI, XII.

divisions or correlations of the rock-groups, and which also renders the interpretations of their age open to a certain amount of doubt.

In mentioning the names of places in Ladák, I have generally made use of the Tibetan name "Lá" for a pass and "Tso" for a lake; thus, "Kangi Lá" for "Kangi Pass," and "Tso Moriri" for Moriri Lake. This avoids such barbarous repetitions as Kangi *Lá Pass* and *Tso* Moriri *Lake*, which one sometimes meets with.

With regard to the propriety of applying the names of the European rock series to the rocks of the Himalaya, in cases where no fossil evidence is available, it appears to me that, since we have in the Himalaya some of the rock-groups clearly indicated as being the homotaxial equivalents of European rocks-groups, it is simpler to apply provisionally to the rocks underlying and overlying such known horizons, the same names as are applied to the similarly placed rocks of Europe. I wish, however, at the same time, as I have observed elsewhere, to impress on the reader most distinctly that I do not for one moment consider that any of the Himalayan rocks are exactly equivalent, either in thickness or in time of deposition, with the correlated European rocks; but that I merely indicate that the rock sequence in the two regions generally follows the same order. It would be equally easy for me to invent new terms for each and every Himalayan rock-group; but it appears to me that when my meaning can be equally well conveyed by the use (in a wide sense) of well-known and well established terms, that it is far preferable to employ such terms than to add to the list of new and little-known ones, which already cumber the paths of science to such an appalling extent.

I.—OLDER PALÆOZOICS OF DRÁS AND LADÁK.

In my last published paper on Himalayan Geology,[1] I have stated that the jaspideous, trappoid and slaty rocks occurring in the neighbourhood of Drás, are found, if traced to the westward into the valley of the Kishenganga, to underlie the limestones of the Carbo-Triassic series, and also to correspond in mineralogical composition to the rocks of the Pír Panjál. It may, therefore, be assumed that both the Drás and Pír Panjál rocks are of pre-carboniferous age, and that they in all probability roughly approximate to the Silurian.[2]

Taking now the Drás Silurian rocks as our starting point, and proceeding in a north-easterly direction along the Ladák road, we shall find that these same

[1] Rec. Geol. Surv. India, Vol. XII, p. 20.

[2] This conclusion will be confirmed in the sequel. Dr. Stoliczka (Geology of 2nd Yarkand Mission, p. 12) compares these Drás rocks to the trappoid rocks of Srinagar, and considers them as certainly the same; from page 16 of the same work we learn that Stoliczka considered the Srinagar rocks, like similar rocks in Cháng-Chenmo, as Silurian. In a former paper (Mem. Geol. Surv., India, Vol. V, p. 349), he considered part of the Drás rocks as Carboniferous.

In the first of these two papers, Stoliczka appears to have considered that the slaty rocks of Drás underlay the Trias dolomites of the Drás river and Mataian, while in his last notes he appears to have considered (as I do) the junction a faulted one; this would account for the two ages assigned to the Drás slaty rocks. In classing them all as Silurian, Dr. Stoliczka's last conclusions agree with my own. In these last notes he also considers the Trias nearest the Drás slates as the newer (Para), whereas in the first paper he classed it as the older (Lilang).

slates and other rocks are continued about as far as the village of Dandál. In this district, these rocks are frequently jaspideous like those on the road from Drás to Tilel (Tilail) described in my above-quoted paper, and they often acquire a black "river-glazing," while they disintegrate into a dark and heavy iron-sand. Occasional beds of the true slates are highly ferruginous and weather to a rusty-red color: there also sometimes occur thin beds of a coarse conglomerate resembling that found among the slates of the Pír Panjál, the occurrence of which confirms the identity of the rocks of the two districts: near Drás the rock is like some of the trappoid rocks of Kashmír.

Still following the course of the Drás river, we find, below Dandál, the rocks gradually assuming a hornblendic character, and not unfrequently containing crystals of pure hornblende of a large size. Near the halting place of Tashgám, the strata are thrown into several small anticlinals, the lowest exposed beds consisting of a dark-colored syenitic gneiss,[1] while the higher beds consist of the Drás slaty rocks: from the latter to the former, there is a complete and imperceptible passage through the above-mentioned hornblendic rocks, so that I come to the conclusion that the lower part of the slate-series has here been altered into gneiss.

From Tashgám to near the junction of the Drás with the Shingo-Shigar river we have alternations of small gneiss anticlinals overlaid by slaty rocks. Some of the latter closely resemble in their mineralogical characters the massive bluish rocks of the Panjál series, which occur at and near Shísha-Nág in Kashmír,[2] while others are like the ferruginous slate rocks of Drás.

Near the junction of the two rivers mentioned above, we come upon a massive light-colored syenitic gneiss (syenitoidite) which seems to underlie conformably the transition rocks.

Another ridge of the same (generally syenitic) gneiss occurs immediately to the north of Drás, apparently underlying the slates of Drás on the one side, and the transitional rocks of Tashgám on the other. I have not traced these rocks far to the north-west of the Ladák road, but I have already mentioned[3] that gneiss pebbles occur in the Búrzil river on the Kashmír and Astor road; and General Cunningham[4] also states that the table-land of Deosai or Deotsu (to the north-west of my map), consists principally of granite, by which he doubtless means the same gneiss: there is, therefore, every probability that a continuous band of these crystallines extends to the north-west of Drás and Kargil. The eastward extension of this Deosai and Drás gneiss will be described below.

The gneiss anticlinals near Tashgám are probably the highest beds of the main gneiss ridges, and are frequently dark colored; but as the main mass of the rocks between the two ridges of gneiss are the same as the slates of Drás, they have been colored of the same tint in the map. We shall, however, subsequently

[1] The whole of the north-western Himalayan gneiss which I have seen, whether hornblendic or micaceous, is granitic in structure, and never distinctly foliated. The hornblendic variety may be termed "syenitoidite," and the micaceous "granitoidite."

[2] Rec. Geol. Surv. India, Vol. XI, p. 44.

[3] Rec. Geol. Surv. India, Vol. XII, p. 24.

[4] "Ladák," p. 57.

see that in Ladák portions of the slate series are sometimes locally altered into a dark-colored gneiss which overlies the massive lighter-colored gneiss, and the same may not improbably be the case with the Tashgám rocks.

To the eastward of Drás, the slaty rocks may be traced across the Suru river as far as a line running nearly from north-west to south-east through Múlhetrúng Station, where the rocks of the great Triassic series appear to be faulted against them. To the south and south-east the same slates overlie the gneiss of Suru and Rúndúm, and were identified by Dr. Stoliczka as undoubted Silurians. If, as I infer from Dr. Stoliczka's notes, the gneiss of Suru is overlaid conformably by the slates, the former may probably be the same as the gneiss of Drás and the Shingo-Shigar river: this question will be discussed more fully in the sequel. The Suru Silurian slates have been traced by Dr. Stoliczka in a band running south-south-east from Rúndúm to the south of Zánskár, and are there continuous with those of North Lahúl and Spiti, which will be referred to again in the third section of this paper.

Returning to the main axis of gneiss to the north of Tashgám, I proceed to trace its eastward extension, and to consider its relations to other rocks to the east. From the junction of the Drás with the Shingo-Shigar river, the gneiss extends to the south-east as far as Kargil and Chattu, where it is overlaid by the Tertiary series. From Kargil I have traced the gneiss down the Suru and Drás rivers as far as the Indus, but did not reach its northern limit. The gneiss in this district is sometimes fine-grained and dark-colored, and at other times coarse-grained and light-colored. At Kargil a very massive light-colored gneiss, without any trace of stratification, underlies the darker and more distinctly stratified upper gneiss.

From Kargil the southern boundary of the crystalline series runs in a generally south-easterly direction.[1] It keeps to the south of the Indus till near the village of Dorgu, when it crosses to the northern bank. To the eastward of Dorgu the boundary forms a sinuous line along the bed of the Indus for some miles; it then runs at some distance to the north of the river, passing close to the villages of Skining, Pharka, Himis, and Ling: from the last-named place the boundary bears to the south-east, till it again joins the Indus at Pittak, south of Leh. To the south-east of Pittak the southern boundary of the crystallines follows approximately the course of the Indus, generally running somewhat to the north, and has been traced as far as a point due south of the Pangúr Lake.

It now remains to say something of the composition, and relations to other rocks, of the Ladák crystallines.

To the south-east of Kargil along the Indus valley the gneiss usually consists of the light-colored massive variety, and has generally a north-easterly dip, so that the older beds appear along the valley of the Indus and the newer towards the top of the Kailás range.

The composition of the rock varies considerably; in most cases, indeed, the

[1] The range on the right bank of the Indus in Ladák has been termed by General Cunningham ("Ladak," p. 43) the "Kailás range," a name which I adopt here: in the "Manual of the Geology of India" this range is called the "Ladák range." This range forms a dominant branch of the range north of the Manasarowar Lake.

rock is a true syenitic gneiss, consisting of quartz felspar and hornblende. This is, however, not always the case, since I have already shown[1] that the gneiss of Drás has a true granitic composition, consisting of quartz, felspar, and two kinds of mica. Near the village of Himis, to the west of Leh, I collected the following varieties of crystalline rocks,[2] *viz.*—

Gneiss.	Mica in small flakes.	(Granitoidite.)
Syenitic gneiss:	*a.* Pink orthoclase.	(Syenitoidite.)
	b. White do.	
Pegmatitic gneiss.	(Pegmatoidite.)	
Hornblende rock	*a.* Small crystals of Hornblende.	
	b. Large ditto.	

The hornblende rock usually occurs in small irregular patches.

At Tánkse, 40 miles to the east of Leh, the greater portion of the gneiss is porphyritic, containing numerous crystals of white orthoclase; near Shushál, 45 miles to the south-east, the orthoclase is pink colored. In the Chimray valley, on the Leh and Tánkse road, the gneiss is traversed in all directions by veins of an intrusive rock, agreeing with some specimens of the albite granite of Dr. Stoliczka. This granite is very light-colored, and consists of quartz, albite felspar, and black mica: the latter occurs in large flakes, and not unfrequently forms a thin coating to quartz crystals of very large size. This albite-granite intrusion is very characteristic of the central gneiss.[3]

With regard to the relations of the Ladák gneiss to other rocks, the most clear sections are displayed near Tánkse and the Pangong lake, and I accordingly commence with those districts. At Tánkse itself we find the crystalline rock to be a massive white, and generally porphyritic, syenitic-gneiss, the higher beds consisting frequently of alternations of dark and light bands. To the south-east of the village of Chilam, near Tánkse, this porphyritic gneiss is distinctly seen to be overlaid by white and greenish quartzitic sandstones, black and green slates, banded jaspideous rocks, a few conglomerates, and the peculiar massive half-slaty half-sandy rock, so characteristic of the Silurians of the Drás river. The whole of the slaty series, both in structure and in position, exactly resembles the slate series of Drás, and there seems to me but little doubt that they are one and the same series. This slate series forms a long narrow ellipse extending from near Tayár, in a south-easterly direction, to a point south of the Pangúr lake. The centre of this ellipse shows here and there a central core of white non-porphyritic gneiss underlying the slates, and forming the highest peaks of the range.

In the Chilam valley the northern boundary of this ellipse appears to be a faulted one, as on the north side of that valley we have hills of gneiss with a northerly dip, while to the south there are dark slates underlaid by gneiss (at the base of valley) with a southerly dip; this fault is apparently continued far

[1] Rec. Geol. Surv. India, Vol. XII, p. 19.

[2] In his last notes (Geology of 2nd Yarkand Expedition, p. 16), Dr. Stoliczka mentions the varied composition of the Ladák gneiss, which he had previously described as syenitic.

[3] Stol.: Mem. Geol. Surv. India, Vol. V, p. 13.
Mc'Mahon: Rec. Geol. Surv. India, Vol. X, p. 221.

to the south-east. To the north-west of Tánkse, the fault, on the other hand, seems to have died out, and the slates appear to rest conformably in a regular synclinal of the gneiss. Taking a transverse section to the south-west from Tánkse *viâ* the Käi Lá, we find to the east of Käi Tso the slate series with a north-easterly dip, underlaid conformably by the white non-porphyritic gneiss of the Indus valley. This gneiss, especially in its higher beds, contains not unfrequently bands of a darker color, as we found to be the case at Tánkse.

Some of the slates, in the middle of the series, between Tánkse and the Käi Lá have been locally altered into a fine-grained, dark-colored, and generally imperfectly crystallized gneiss, quite distinct in character from the underlying white gneiss. Further to the north-west on the road between Tánkse and the Chang Lá, the upper dark gneiss, altered out of the slates, is seen resting on and passing down into the white gneiss of Tánkse. This section, therefore, establishes the important fact that there exists in Ladák gneiss of two distinct ages...one altered out of Silurian slates, and another underlying such slates, but apparently also, at all events partly, altered out of an older conformable series. This fact may lead, as mentioned, to the inference that the darker colored and higher gneiss of Kargil, already referred to, may really very possibly be the altered Silurians, though, as before said, the question cannot at present be definitely settled.

As already stated, the white gneiss of the Indus valley dips generally to the north-east, and the higher beds consequently form the summit of the Kailás range. Along the greater part of the Indus valley in Ladák the white gneiss continues to the crest of the range, but near Leh itself, below the Khárdong Lá[1] and Láswan Lá, we find the white syenitic gneiss overlaid by alternating bands of dark and light-colored gneiss like the higher gneiss of Tánkse and the Käi Lá. This striped gneiss is again succeeded by an imperfectly crystalline, dark-colored, and fine-grained gneiss, alternating with partially altered slaty rocks, and occasional unaltered slates. These rocks appear to occupy a synclinal ellipse in the white gneiss, the boundaries of which are approximately indicated on the map. From the nature and position of these rocks, I have little doubt but that they are the altered equivalents of the slates to the south of Tánkse, and they have been colored accordingly in the map ; this is, however, only a conjectural correlation.

To the northward of Leh, the crystalline series has been traced by Dr. Bellew along the Shahidúla and Yarkand road as far as Sá-Sango where it appears to be succeeded by Silurian slates.

Returning once again to the Tánkse district, we find that the range to the south-east of Tánkse, running parallel to the north-western half of the Pangong lake, consists of the porphyritic gneiss of Tánkse. This gneiss I have traced some distance to the south-east of Shushál, where it is overlaid by Silurian slates, connecting those to the south of Tánkse with those of the Pangong lake, which will be referred to immediately. On the northern flank of the

[1] This pass is called on the Topographical Survey maps the Laowchi Lá, though it is always spoken of by the natives as the Khárdong Lá.

Tánkse range, to the north-east of Tánkse, we have a regular ascending series of gneissic rocks. The higher beds become gradually interstratified with unaltered slates and sandstones, with some banded jaspideous rocks; till finally all gneiss disappears, and the series consists solely of slaty and sandstone rocks, corresponding exactly in mineralogical character with the slaty series to the south of Tánkse. The transition from the crystalline to the slate series is, however, here so very gradual that only an arbitrary boundary can be drawn, but the higher gneissic rocks are probably altered Silurians.

The slaty series I have traced to the north-west to the Shyok river, and to the south-east, along the whole length of the Pangong and Pangúr lakes: its north-eastern boundary I shall refer to subsequently. Near Bapi Station to the south-east of the Pangúr lake, the slates are underlaid by a core of granitoid gneiss. We have already seen that to the north-east of Tánkse there is a regular sequence from the crystalline to the slate series; along the south-western shore of the Pangong lake, on the other hand, the junction between the two series seems to be a faulted one, the black slates and green shales and sandstones which form a narrow band along this shore of the lake dipping towards the gneiss. Still further to the south-east the junction again appears to be a normal one. In the mineralogical composition of the rocks surrounding the Pangong lake, there is very great variety, but with one exception they consist mainly of colored slates, shales and sandstones. I have already mentioned the composition of these rocks on the south-western shore of the lake, and need not, therefore, refer to them again. On the opposite shore, in addition to the rocks of the south-western shore, there also occur banded jaspideous rocks, together with the slaty-sandy rock of the Drás river, and true slates which weather to a rusty red color like those in the neighbourhood of Drás, already noticed. The mineralogical composition of these Pangong rocks affords by itself alone abundantly sufficient evidence to show that they are the equivalents of the slate series of Drás and of the country to the south of Tánkse.

At the north-western extremity of the Pangong lake, where the original relations of the rocks have been greatly disturbed by faulting and inversion, there occurs a great local development of a glistening white saccharoid quartzitic sandstone or quartzite, which superiorly gradually becomes calcareous, and passes by imperceptible degrees into a pale blue limestone. This rock overlies the slate series of the Pangong lake, and is apparently faulted against the ridge of gneiss to the south. This very characteristic saccharoid sandstone and limestone is precisely similar in mineralogical composition to the rocks underlying the Triassic series in South Rupsu, which we shall subsequently show to be probably of Carboniferous age. This identification confirms our conclusion as to the Silurian age of the slaty rocks of Pangong and Drás, the former of which underlie the sandstone and limestone.

Some miles to the south-east of the village of Shushál, at the Saki Lá, and elsewhere in the neighbourhood, there occur other outlying masses of blue limestones and white sandstones, which seem undoubtedly to be the same as those at the north-western end of the Pangong lake.

The Pangong slates lie to the north against a ridge of gneiss which runs in the normal Himalayan strike, on the line of the Marsemik pass. To the south-east of the Tátar camp at Chagra, the slates appear to be faulted against the gneiss, but to the north-west of a spur of gneiss running towards the south from Chagra, the slates conformably overlie the gneiss. The highest beds of the gneiss consist of alternations of light and dark bands, some of the latter being garnetiferous, like similarly situated gneiss in Pángi.[1] The gneiss of the Másemik Lá itself is usually porphyritic like that of Tánkse; to the north-west it is continued to the valley of the Shyok, and to the south-east I have traced it some distance over the border into Chinese Tibet. This ridge of gneiss appears to form an anti-clinal axis, since on the north side of the Másemik Lá it has a north-easterly dip, and is overlaid conformably by slates, sandstones, jaspideous rocks, and the before-mentioned massive, slaty-sandy, or trappoid rock, so characteristic of the Drás Silurians. Many of the higher beds of the crystalline series consist of a dark-colored hornblendic rock with bronzite, similar to a rock which occurs in the same position in the Tánkse valley section. These massive trappoid rocks were apparently considered by Dr. Stoliczka[2] to show some signs of an igneous origin, and also to show some resemblance to the Silurian series of Srinagar; my own opinion is, that none of these rocks are of igneous origin, though they do, undoubtedly, very closely resemble some of the trappoid rocks of the Kashmir Silurian series, some of which have probably been brought to their present condition by metamorphic action.[3] From the summit of the Másemik Lá to the bed of the Cháng-Chenmo river, we have a generally ascending section through these same slaty rocks: a short distance on the north side of the pass, some of these rocks have been locally altered into a dark-colored gneiss, similar in character to that which I have already referred to, as occupying a corresponding position in the Tánkse valley. On the Cháng-Chenmo river, the slate series seems to be faulted against massive Triassic limestones, which I shall notice again in the succeeding section of this paper.

Dr. Stoliczka[4] seems to have considered that the gneissic rocks of the Másemik Lá were an altered portion of the slate series of the Cháng-Chenmo valley, and that consequently both were of Silurian age. There appears to me, however, to be a clear case of the superposition of the latter on the former, as in the other sections of similar rocks already described.

The rocks to the south of the Cháng-Chenmo valley, as I have said, were referred by Dr. Stoliczka[5] to the Silurian. Dr. Stoliczka also compares these rocks to the trappoid rocks of Srinagar, whence we may conclude that he also considered them to be Silurian. Both these rocks are, however, similar in character to those to the south of Drás, which Stoliczka[6] at first classed as Carboniferous, but which appear to me to be Silurian.

[1] Rec. Geol. Surv. of India, Vol. XI, p. 54.

[2] Manual of Geology of India, p. 653.

[3] See Rec. Geol. Surv. of India, Vol. XI p. 36, *et seq.*

[4] Geology of Second Yarkand Mission, p. 16.

[5] *Ibid*, p. 16.

[6] Mem. of the Geol. Surv. of India, Vol. V, p. 349.

This completes the description of the older palæozoic rocks of the Drás district, and of the northern bank of the upper Indus, as far as I am at present acquainted with them. A further discussion as to their precise geological age, and as to their relations with the palæozoics of other regions of the Himalaya, will find a more suitable place in the concluding section of this paper.

II.—ROCKS NORTH OF CHANG-CHENMO RIVER.

In the previous section of this paper, I have traced the Drás slaty series as far as the left bank of the Cháng-Chenmo river, where it is separated, by what seems undoubtedly to be a faulted line, from a totally distinct series of rocks which forms the low cliffs on the opposite bank; the two series of rocks occur on a broken anticlinal axis.

The rocks on the right bank of the river are to a great extent composed of the characteristic white Triassic dolomitic limestone so frequently referred to in my former papers: a short distance north of the river, these rocks are traversed by a synclinal axis. The higher beds exposed in this synclinal are hard and crystalline, while the lower beds consist mainly of a soft white dolomite like that of Amrnáth cave in the Lidar valley of Kashmír; some soft reddish shales and a brecciated red conglomerate occur locally in the lower beds. *Megalodon* is of common occurrence in these limestones, and Dr. Stoliczka also obtained from them *Dicerocardium*;[1] there can, therefore, be no doubt as to their age.

To the northward these Triassic dolomites are underlaid by carbonaceous shales, not unfrequently containing crinoids and, according to Dr. Stoliczka-fucoids, and then again by dark slaty shales, sandstones, and occasional lime, stones, forming a somewhat folded series. Still further north, these rocks are underlaid by an anticlinal of rocks which seem to be the Silurian Drás series, which, according to Dr. Stoliczka, are again succeeded further north by Carboniferous and Triassic rocks, the latter probably forming the greater part of the dreary plains of Depsang, to the north of my map.

From the relations of the crinoidal shale and sandstone series to the Trias dolomite, I consider that the former rocks must undoubtedly be considered as of Carboniferous age—an opinion also held by Dr. Stoliczka who noticed their resemblance to the rocks belonging to that period in Spiti.

In the Cháng-Chenmo valley the notes of Dr. Stoliczka[2] make mention of some sandstones and conglomerates which he doubtfully considers as the representative of the Ladák Eocenes. These rocks are also much mixed with shales, and when I first entered the Cháng-Chenmo valley, I was at once struck with their resemblance to the Tertiaries; the sections are a good deal obscured by debris, but I found a portion of a conglomerate, which is strikingly like the Tertiary conglomerate of Miru (described below), distinctly underlying the Trias dolomite; and I think that these doubtful rocks belong to the Carboniferous series, the strong resemblance of which to the Tertiaries elsewhere will be noticed in the sequel. There are certainly no Eocene rocks on the Pangong lake, such as are

[1] Geology of Second Yarkand Expedition, p. 17.

[2] *Ibid.*, pp. 17-18.

referred to (probably by some clerical error) in the above-quoted passage from Dr. Stoliczka's notes.

III.—Rocks of the Ladák and Zánskár basin.

I now come to the consideration of a series of rocks mostly newer than those of which I have already treated, which occupy a large elliptical area bounded to the north by the crystalline series described in the last section, and to the west and south by the Silurians which rest on the gneiss of the Zánskár range, already described in a previous paper.[1] The area occupied by these rocks comprehends a considerable portion of Ladák and nearly the whole of Zánskár, together with parts of Rupsu and other districts. As Ladák and Zánskár form the greater part of this area, it may be well termed the "Ladák and Zánskár basin." The whole of this large area has not at present been completely surveyed, owing to the very difficult nature of the country, but sufficient is known to indicate the general distribution of the rocks. I have said that the greater portion of the rocks in this area are newer than those previouly treated of; but from the south-eastern extremity of the basin a ridge of older rocks runs up, separating this end of the basin into two divisions. I shall treat of the rocks of this area in their serial order, commencing with the Tertiaries. It may be observed that the long axis of this basin or ellipse has the normal Himalayan north-westerly and south-easterly strike.

The Tertiaries.

The Tertiary series forms the north-eastern band of the area under consideration and, rests immediately on the Ladák crystallines. Coming from the west, these Tertiary rocks are first met with close to the town of Kargil, where they rest unconformably upon a denuded surface of the syenitic gneiss, and have a low and regular dip to the south-east. Masses of the gneiss may here and there be observed within the Tertiary area, protruding through the newer rocks. The lower beds of the Tertiaries near Kargil consist of soft grey and brown sandstones, shales, slates, and limestones, with here and there bands of conglomerate. Near the village of Pashkám the dip of the rocks has increased, being about 40°, and the higher beds, which are here well exhibited, consist of bright purple and green shales and sandstones, with occasional bands of a yellowish sandy limestone.

The northern boundary of the Tertiary zone is continuous with the southern boundary of the Ladák crystallines, and need not be exactly traced, and I, therefore, at once proceed to describe certain sections of the Tertiaries which will best exhibit the general characters of these rocks.

It may, first of all, be observed as a very important point, that along the whole of the northern boundary of these rocks, from Kargil to south of the Pangúr lake, (a distance of nearly 200 miles), the dip of these rocks is to the south-west, and that to the westward of Leh the same dip continues (with an occasional exception) throughout the entire width of the series. For some distance to the west of Leh this dip seldom exceeds 30° or 40°, and is of great regularity,

[1] Rec. Geol. Surv. of India, Vol. XI, p. 52.

and free from contortions. To the east of Leh these rocks, except along the northern border, have undergone a greater amount of disturbance.

The sections which exhibit most clearly the relations of the Tertiaries and the gneiss are found below the point where the Kashmír and Ladák road enters the valley of the Indus at Khalchi. Near the village of Inamdoh the lower Tertiaries, here consisting chiefly of slates and sandstones, are seen resting unconformably upon a denuded escarpment of the gneiss. The surface of the escarpment has an average slope of about 25° to the south-west, this slope being irregular and bearing numerous hillocks and hollows: the dip of the gneiss is to the north-east.

The Tertiaries rest upon this sloping and denuded surface with a dip slightly lower than the plane of the slope. The lowest beds of the Tertiaries, which occur at the base of the slope, are cut off higher up by the projecting hillocks of gneiss, while the higher beds extend considerably further up the slope, thus showing a clear case of overlap. Numerous analogous sections may be seen in the neighbourhood, but the one quoted affords ample evidence to prove that the junction between the two series of rocks is a natural one, and that the Kailás crystalline range formed the old shore line of the gulf in which the Tertiaries were deposited.

I have said that at Inamdoh the lower Tertiaries consist of slates and sandstones; this composition is, however, not constant in the neighbourhood, since we not unfrequently find the lower slates replaced by coarse conglomerates containing rolled pebbles of the crystalline and other rocks. This conglomerate is of great thickness on the Khalchi and Dhúmkar (Dhumkur) streams, and it seems, from here to Leh, to occur on all the tributary streams descending from the Kailás range of crystallines to the Indus, and not in the intervals between such streams. If I am right in this interpretation, and I think I am, we must conclude that the drainage system of the southern side of the gneiss range followed the same approximate lines during the deposition of the Tertiary rocks, as it does at the present time.

A transverse section from north to south of the Tertiaries at Khalchi may be taken as a typical example of the series in this district. The lower beds, as we have already seen, are composed either of conglomerates, grits, sandstones, or slates, according to their relative position to the streams. The sandstones not unfrequently show ripple-mark, and the slates are generally grey in color, very hard, and almost indistinguishable in hand specimens from the palæozoic slates which occur to the south of the Tertiaries. The succeeding zone of beds consists of orange and brown calcareous sandstones, with occasional shales. These are followed by purple and green shales which are almost indistinguishable from some of the Subáthu rocks, and which are well represented on the Indus at Khalchi and Basgo. Between the villages of Kalchi and Nolra, in the Indus valley, a thick band of coarse, blue, shelly limestone overlies the colored shales. This limestone may also be seen on the Kashmír and Ladák road at the junction of the Láma-Yuru stream with the Indus, and again on the Zánskár river to the south of Nímo, so that it doubtless forms a continuous

band. In this limestone near Khalchi[1] I found a species of *Turbo*, and numbers of little disks which I believe to be Nummulites, though their structure is obliterated. On the Zánskár river, on the other hand, nummulites are extremely abundant in this limestone, and water-worn pebbles exhibiting sections of these fossils show the banks of the Indus at Nimo.[2] The nummulite, which is characteristic of this limestone, is, Mr. Blanford informs me, *N. raymondi*, an Eocene species, which fixes the age of these rocks: this species with *N. exponens* were obtained from these rocks by Dr. Stoliczka.

In the Indus valley between Khalchi and Nimo the nummulitic limestone is overlaid by several feet of a coarse conglomerate, containing pebbles of the underlying limestone: this conglomerate is apparently conformable to the limestone, and is succeeded by shales and slates. The Tertiary sedimentary series near Khalchi may be tabulated as follows:—

UPPER ...	Shales and slates. Limestone conglomerate. Nummulitic limestone.
MIDDLE ...	Purple and green shales and sandstones. Orange and brown calcareous sandstones and shales.
LOWER ...	Grey and brown slates, sandstones, grits, or conglomerates; the sandstones often ripple-marked.

Such is the normal section of the Eocenes at and below Khalchi: above the latter place, on the other hand, a very different condition prevails in the lower beds. On the Saspúl stream the boundary between the Eocenes and the Palæozoics runs close to the upper Kashmír and Ladák road. The lower Eocenes, which are inclined to the south-west at an angle of about 25°, consist of very soft brown and yellow sandstones, very frequently showing cross-bedding. In these sandstones are embedded vast quantities of blocks of the gneiss of the Kailás range, many of them several feet in diameter. Some of the isolated blocks showed the sandstone strata bending down below them, as if they had been dropped from above on to the still soft sand: two blocks were polished in a manner suggesting ice-action. The soft sandstone, with its boulders, lies unconformably on the gneiss, corresponding in position to the lower slates and conglomerates of the Khalchi section: it is overlaid by harder green shales and the middle Eocenes. Near the village of Ling the lowest strata consist of soft colored gypseous shales with occasional bands of a compact buff limestone; this limestone contains numerous specimens of a large species of *Estheria;* these strata are again overlaid by the purple Subáthu-like rocks. At Nimo again, there occur soft sandstone strata with embedded gneiss blocks, which are very

[1] It is mentioned by Mr. Davidson, in describing some fossils collected in Ladák by Col. (then Capt.) Godwin Austen, (Q. J. G. S. L., Vol. XXII, p. 38) that Hippurites were seen in a rock at a place called Kalatys on the Upper Indus; I think that Kalatys must be the same place as Khalchi, which is also called Kalatse. I should, however, be very much inclined to doubt the occurrence of *Hippurites* either at this place or anywhere else along the Upper Indus, the course of which lies in or near the Tertiaries.

[2] I spell this name and numerous others without the initial S, which seems generally to be omitted in pronunciation. Similarly, Nolra for S'Nolra, Kio for S'Kio, Tok for S'Tok. Properly also Piti for S'Piti, but the spelling Spiti has acquired a general acceptance.

slightly inclined, but which from their structure seem to correspond with the lower Eocenes of the Saspúl stream; their relations to the higher Eocenes are not, however, well displayed, and to the south-east they are concealed by a modern boulder deposit, which also covers the base of the Tertiary series near Leh, where it has been much denuded away along the valley of the Indus. Above Leh, however, near the village of Arpa, we find the hard gneiss conglomerate occurring low down in the Tertiary series, underlaid along the bed of the Indus by soft gravels, conglomerates, sandstones and clays with a south-westerly dip of about 15°. The conglomerate contains pebbles of a trap, which is thus shown to be of *infra*-Eocene age, but whose origin is not certain: the lowest conglomerate also contains pebbles of blue limestone and buff dolomite probably derived from rocks of the Carbo-Triassic series, and indicating former outcrops of these rocks now probably concealed by the Tertiaries. Occasional blocks of gneiss, several feet in diameter, occur in the sandstones. From the softness of these rocks they have in great part been denuded away by the Indus, and only patches remain here and there.

I can but think that ice-action has played some part in the formation of these lower Eocene strata, as it seems to me very difficult to imagine that water power alone could have placed these blocks in their present position without scouring out the soft sand in which they are embedded. I have, however, no positive proof to bring forward in support of this view.

I will now describe two sections taken across the nummulitics higher up the Indus than the former, the first being an ascending and the second a descending section. The first section is taken from the Indus valley below Leh to Kio in Zánskár. The lowest nummulitics exposed on the Indus near the village of Phay, consist of brown and green sandstones, mingled with coarse conglomerates and grits; the sandstones are often ripple-marked, and the pebbles in the conglomerate consist mainly of gneiss, while the grits are composed of coarse gneissic sand precisely similar to that which at the present time is found in the valley of the Indus. In the higher part of the series, near Urúcha, purple and green shales and slates succeed and partly replace the grits, forming an anticlinal resting upon green and brown splintery shales. The higher slates contain numerous bands of earthy limestone abounding in nummulites: the latter are particularly common near the village of Shingo,[1] where I also obtained a species of *Conus*. The rocks are here much folded, but the foldings are regular and open, and never show the minute contortions and crumplings so characteristic of the older rocks. Some 2 miles above the village of Kio the nummulitic rocks are overlaid by several hundred feet of a coarse conglomerate, which is here nearly vertical. The relation of this conglomerate to the shales is not very clear, but it appears to lie in a synclinal axis, being again underlaid by colored shales nearer Kio; the great mass of purple shales are, however, unrepresented below the conglomerates at Kio; close to the latter place the Tertiaries are underlaid unconformably by Carboniferous rocks. The higher Tertiary conglomerate, here and in other parts of the same line, contains numerous pebbles of the

[1] The village of Shingo is placed in the Atlas Sheet 1½ or 2 miles too near to Kio.

underlying nummuliferous limestone, clearly showing that the former rock is the newest of the Tertiary series.

The next section is taken down the Gía river from Látho to Upshi on the Indus. On the left bank of the river at Látho the upper conglomerates are nearly vertical, but with a slight northerly dip: they rest to the south on green and purple shales, with false bedding, which at first sight has somewhat the appearance of unconformity; this is, however, but a local condition, and on either side conformability is clear. The conglomerates, which can be traced continuously along the southern border of the Tertiary zone from Kio to this point, form a regular synclinal axis, and as they descend gradually alternate with greenish-colored sandstones: they contain pebbles both of the older Tertiary and of the neighbouring Palæozoic rocks. Further down the Gía river, these conglomerates are underlaid by green and red shales, sandstones, grits and conglomerates; and the whole series is much contorted. Near the village of Míru, the highly colored shales are underlaid by a considerable thickness of conglomerate: these conglomerates contain chiefly pebbles of gneiss, of carboniferous quartzitic rock, of some unknown silicious rocks, and irregular fragments of the lower Tertiary shale. This conglomerate has acquired a kind of false slaty-cleavage, splitting into thin plates, right through the pebbles, and parallel to the stratification. Below the conglomerate we find an anticlinal axis of brown and green crumbly shales and greenish sandstones, which are again overlaid, towards the Indus valley, by the red shale series. At the very base of the Míru anticlinal there occur some brown and black carbonaceous shales alternating with bands of quartzite, which correspond so exactly in mineralogical character with the Carboniferous rocks of Gía (see below), that they are, I think, the same. These lower rocks seem to have the same dip as the Tertiaries, and as the two are very similar in mineralogical character, it is not easy to distinguish between them. The great similarity between the Eocene and Carboniferous shales at Shargol will be noticed below. If the identification of these Carboniferous rocks is correct, it would appear that we have here a case of parallelism between these rocks and the Tertiaries, and that the former must have been approximately horizontal at the time of the deposition of the latter.

Below Míru there is an alternating series of red and green shales and sandstones, with occasional bands of gneiss conglomerate. About 2 miles above the village of Upshi, these rocks are underlaid by hard and coarse gneiss conglomerate, several hundred feet in thickness, again underlaid by the softer rocks of the Indus valley, already referred to. No nummulites were met with in this section.

From the preceding sections it seems to me probable that the green and brown crumbly shales of Míru and Urúcha, together with some of the overlying conglomerates, are the equivalents of the lower gneiss conglomerate of the Indus valley, since both these groups are overlaid by the red shale series. It is further not improbable that the red shales once overlapped the gneiss conglomerate in the Indus valley, and extended some distance further up the crystalline rocks of the Kailás range.

It will be noticed that throughout the Tertiary series (above the gneiss con-

glomerates), there is evidence of local contemporaneous denudation, and that the southern conglomerate is formed in part of fragments of the denuded nummulitic zone, which I have shown to be relatively high up in the series. I have also shown that these higher conglomerates are underlaid by only a small thickness of shale, on their southern border, and it, therefore, seems probable that these newer strata overlapped the older along this border, such overlap being possibly due to local subsidence.

It now remains to treat of the southern boundary of the Eocenes, in the course of which we shall have to discuss a large mass of volcanic rocks which occur along this line. Commencing our survey at the western extremity of the zone, we find that the purple shales of Pashkám are overlaid by a great mass of basaltic trap which here consists of greenish anamesite, weathering to a pale brown color. South of Pashkám the traps may be traced continuously to Shargol (Shergol), a width of 10 miles, their western boundary running south-south-east from Kargil and adjoining the Palæozoics of Tashgám. At Shargol we find outh of the main trap outflow, a band of soft yellow calcareous sandstones, and purple, green, and black shales, exactly resembling the sedimentary Eocenes of Pashkám, and which are doubtless part of the same series. This band may be traced along the southern border of the trap as far as Múlbeck. The rocks of this band are much mixed up with trap, and in many places within the trap area masses of altered sedimentary rocks are met with, which are probably fragments of the Tertiaries which once extended continuously over this area, but which have been broken up and altered by the subsequent intrusion of the trap. From Shargol the southern boundary of the trap runs a little to the north of Múlbeck, and thence north of the Kashmír and Ladák road. At and near Báma-Yuru, the trap is much mixed up with Palæozoic rocks which I shall refer to subsequently; east of the last-named village the southern boundary runs north of the village of Wanla, and thence on the north of the stream flowing from the Choki-Lá. From Pashkám the northern boundary runs for some miles in an easterly direction, then bends to the south-east till it touches the Indus at Khalchi, from which point it again leaves that river and forms the summits of the high range on the left bank, gradually dying out among the sedimentaries to the west of the Zánskár river.

The trap throughout this series consists of fine-grained anamesites, green-stones, basalts, and serpentines, with occasional amygdaloids; it is never porphyritic, and when worn into pebbles acquires a brown-black glaze like the darker varieties of hæmatite.

I have already said that these traps die out a little to the west of the Zánskár river, in consequence of which the main mass of the sedimentary Tertiaries comes into direct contact with the Carboniferous rocks, which form the zone to the south of the Eocenes. Between Kio and the Zánskár river, the Eocenes, with a low northerly dip, rest upon and overlap the Carboniferous rocks, masses of the latter often protruding through the former, showing that we have another natural boundary, indicating the original southerly limit of the Eocene series.

In the Zánskár river, during its course through the Tertiaries, there were found, during the summer of 1878, large masses of pure native copper which had

been washed from the neighbouring rocks. The copper occurred in irregular nodules of many pounds weight. I could not discover the copper *in situ*, and cannot therefore say positively whether it was derived from the Tertiaries or from the older rocks further south.[1]

To the south-east of Kio the Tertiary boundary runs near the right bank of the Markha river, crosses the Ladák and Kulu road at Látho, thence continues along the left bank of the Indus towards the Chinese frontier. The coarse conglomerates that form the highest beds of the series between Kio and Látho may be traced far to the east of the latter place. On the Markha river between those two places, masses of trap occur on the southern border of the Eocenes. This trap is of a highly crystalline structure, and not like the compact greenstones and serpentines of Shargol.

The line of occurrence of this trap is generally near the junction of the Palæozoics and the sedimentary Tertiaries, as is well seen near Gía, where the trap has clearly intruded among the Palæozoic limestone, which is here full of *Encrinites*.

On the Markha river and to thesouth-east of Gía, numerous trap-pebbles are included in the upper Tertiary conglomerate; but it is not clear that these pebbles belong to the same mass of trap as the one on this line.

The large mass of trap on the upper Indus above Leh forms a ridge-shaped mass, extending between the sedimentary Tertiaries to the north and the gneiss of Rupsu to the south. The upper Tertiary conglomerate near Gía and to the eastward contains pebbles of trap, of crinoidal Carboniferous limestones, of Rupsu gneiss, and of the lower Tertiary rocks. South-east of Gía the band of Carboniferous rocks dies out, and the Tertiaries are in direct contact with the gneiss of Rupsu.

Along the whole of the southern border of the Tertiaries to the east of the Zánskár river, these rocks have been much disturbed, and are not unfrequently inverted; from the distinct occurrence of overlap here and there, it seems probable that this boundary, like the northern, indicates the original limit of the area in which the rocks were deposited: the trap has, however, probably disturbed the original relations of these rocks.

The occurrence of nummulites in the higher Eocene rocks proves that these beds are of marine origin. Many of the lower littoral beds, on the other hand, from their heterogeneous composition, and from the frequent occurrence of cross-bedding, appear to me very probably to be of fresh-water or brackish origin. In the lower beds near Kargil, Mr. Drew obtained some gastropods allied to *Melania*, and some bivalves which seem to me to be *Unio* and *Dreissena*, though Dr. Stoliczka[2] considered them as *Pholadomya* or *Panopæa;* if my interpretation be correct, it confirms the fresh water origin of these rocks, which is borne out by the occurrence of an *Estheria* near Leh.

The above facts lead, I think, to the conclusion that the nummulitic rocks of the upper Indus valley were deposited in a narrow arm of the sea (as was

[1] General Cunningham ("Ladák," p. 22) says that the name Zánskár (or more correctly Zángskár) means "white copper" or brass; and at p. 234 of the same work, he concludes from this meaning that copper must occur in that country, though he could not hear of it.

[2] Mem. of the Geol. Surv. of India, Vol. V, p. 348.

suggested by Dr. Stoliczka), the borders of which were rendered brackish by the influx of fresh water. Subsequently to the deposition of these rocks, the southern border of the western half of the zone was broken up by a large mass of basaltic trap which followed the normal strike of the Himalayan rocks, as being in all probability the line of least resistance. The Kailás range formed at a lower elevation the northern shore line of this gulf, while the southern shore line in all probability followed the northern boundary of the Palæozoics of the Zánskár basin, and of the trap of the upper Indus.

At the time of the deposition of the nummulitics, the upper Indus valley must have been a wide depression below the level of the sea, flanked on either side by land. Since the Eocene period this valley has been raised to an elevation of 10,500 feet above the sea-level below Leh, and it is in all probability owing to this elevation that the Tertiaries have obtained their present generally south-westerly dip. This elevation of the Tertiaries (together, of course, with the surrounding rocks) to the north-west of the Zánskár river, must have been so gradual and even as not to disturb the original relations of the rocks, and, judging from the southerly inclination of the Tertiaries, was probably of greater vertical extent on the northern than on the southern side of the Indus. To the south-east of the Zánskár river, where the Tertiaries attain the enormous elevation of 21,000 feet (as in Tok (Kanri) peak, opposite Leh), the disturbance which they have undergone is considerably greater than to the west (where their elevation is less), and their southern boundary is often faulted.

In the former area, however, these rocks do not seem to have undergone the puckerings and crumplings to which the Palæozoics have been subjected, the movements causing which would seem to have taken place before the Eocene period. It seems not improbable, from the prevalence of the south-westerly dip in the Tertiaries, that their northern border was first elevated, and that to the east of the Zánskár river, the higher conglomerates were deposited in a narrow valley at the base of this newly elevated Tertiary land, which was then rapidly undergoing denudation.

I am thus led to the belief that the great contortion which the pre-Tertiary rocks of Ladák have undergone took place in great part, at all events, previously to the nummulitic period, and from the presence of Jurasso-Cretaceous rocks (and no newer secondaries) in Zánskár (see below), that this contortion and denudation took place in the later Cretaceous period when the country (except the Indus valley) first emerged from the sea, beneath which it has probably ever since been buried.[1] From his observations in the Sub-Himalayan region, Mr. Medlicott[2] came to the conclusion that the contortion of the older rocks there took place after the Nummulitic period, and he pointed out the importance of comparing this relation with that in the Central Himalaya, where a different condition might prevail.

[1] Against this view there is the apparent parallelism between the Tertiaries and Carboniferous on the Gía river, which would indicate, if rightly interpreted, that here the great part of the disturbance was of post-Tertiary age. This is borne out by the greater amount of metamorphism and contortion which the Tertiaries to the south-east of the Zánskár river have undergone in comparison with those to the north-west.

[2] See "Manual of Geology, India," p. 684.

The Indus valley Nummulitics seem to indicate that the enormous elevation of the Central Himalaya did not take place at all events till post-Eocene times, while the elevation and contortions of the outer Siwaliks render it probable that the elevation of the whole Himalaya has occurred in great part since the period of the older Pliocene.

It may not improbably be, that in the Ladák Himalaya, lateral crushing had taken place before the Eocene, and brought the pre-Eocene rocks approximately into their present positions, during which a great smashing and crushing of these rocks must have taken place; the pre-Eocene rocks were then denuded. During the deposition of the Ladak Eocenes there was a pause in the lateral crushing action succeeded by another period of lateral crushing; this second crushing must have raised the Ladák mountains to their present height, during which elevation the Tertiaries were not so much smashed up as the lower rocks during the first crushing, but were, so to speak, carried up on the top of them. The post-Eocene period of lateral crushing was also probably post-Pliocene, and was the one which also crushed up the Siwaliks. These latter rocks with their underlying Nummulitics, being on the boundaries of the central elevated mass, would necessarily undergo much more crushing and smashing than the Eocene rocks of Leh, which, as I have said, might be carried up by the lateral movement on the top of the denuded older rocks with but comparatively little crushing.

Older Rocks.

I now come to the consideration of the pre-Tertiary rocks of the area under discussion, and commence my survey at the north-western end of the basin.

When treating of the slaty series of Drás, I have already shown that those rocks do not extend to the westward of a line running south-south-east about 16 miles to the east of the Kúrtse, where they are cut off by newer rocks. I have also shown that the Tertiary zone does not extend much to the south of either Shargol or Múlbeck, and a line running at first east and then south-east of the latter place. The rocks we have now to consider occupy the angle between the two lines, and extend far to the south-east into Spiti: a few of these rocks extend within the Tertiary area in the neighbourhood of Láma-Yuru.

Before going further, it may be well to mention that the rocks now to be noticed range from the Silurian to the Cretaceous, and that the great mass of those above the Carboniferous consist of the Triassic series. Most of these rocks were originally named by Dr. Stoliczka in the Spiti district, where they are all fossiliferous, and their divisions are tabulated on pp. 135 and *seq.* of his above quoted memoir. The strata above the Carboniferous (Kuling) were divided into upper Trias (Lilang), Rhætic (Para limestone), upper Rhætic or Lower Lias (Lower Tagling), and various higher groups of Jurassic and Cretaceous age. In most of the country examined by me where supra-Carboniferous mesozoic rocks occur, I have only here and there been able to identify the separate groups of Stoliczka, which all form part of one great rock-series, easily recognised by the great prevalence of limestones and dolomites. I have not been able to color these different groups separately in the map, and they are, therefore, all embraced in the large area colored sienna in the map, which must, accordingly,

be understood to comprehend strata ranging throughout the upper Trias (under which I include Rhætic) to strata of lower Liassic or upper Rhætic (lower Tagling) age. As I shall notice, there may possibly be some even newer strata included here and there in the area, though in the absence of fossil evidence I cannot be certain. Whenever I have been able to recognise any of Stoliczka's minor divisions I have mentioned them. It may be observed that in his second paper on Western Tibet, Dr. Stoliczka was disposed to unite the Trias and Rhætic [1]

I commence my examination of the pre-Tertiary rocks of the Zánskár basin at its north-western extremity.

To the south and south-east of Shargol (Shergol), to quote the words of Dr. Stoliczka,[2] "the higher hills all consist of Triassic limestone, alternating near the base with rather highly metamorphic, and sometimes strongly carbonaceous shales, which it is very difficult to distinguish from the Tertiary beds," which I have already shown to occur to the north of and at Shargol. Dr. Stoliczka goes on to say that the determination of the Triassic limestone is tolerably certain, and that it is the same as that which occurs above Drás. The latter was considered by Stoliczka[3] as the representative of the Keuper (Lilang) in its lower part, and apparently of the Para limestone in its upper and more dolomitic part. We shall subsequently see that the Shargol limestone underlies other dolomitic strata which are probably the representative of the Para, the Shargol limestone being the Lilang.

It does not appear that Dr. Stoliczka found any fossils in the Shargol limestone: in the stream running to that place from the south there, however, occur numerous blocks of a blue limestone full of a species of a large *Megalodon*, though I did not find the fossil *in situ*. These fossils seem to differ from *Megalodon triqueter*,[4] characteristic of the Para limestone, by the larger size of the umbones, and by the deeper groove between the two valves. To Dr. Feistmantel and myself the species appears to be indistinguishable from *Megalodon gryphoides* of Gümbel,[5] characteristic of the European Keuper. We have, therefore, pretty fair evidence that the Shargol limestone is upper Trias.

Dr. Stoliczka, in the notes of the Yarkand journey, goes on to say that the Triassic limestone can be traced to the south of Kárbu (Kharbu) and the Fotu-Lá; and he further observes, that this limestone near Kárbu and on the Fotu-Lá is underlaid by shales, which he classes as Carboniferous, and which he traced as far as Láma-Yuru. These shales are generally carbonaceous and weather to a peculiar light brown color, and as they underlie the upper Triassic Shargol limestone, they may in all probability be classed as Carboniferous, since according to Stoliczka,[6] the Lilang (upper Triassic) series in Spiti overlies (with here and there unconformity) the Kuling (Carboniferous) series; the Permian and Lower

[1] Mem. Geol. Surv. India, Vol. V, p. 352.
[2] "Scientific Results of Second Yarkand Expedition," Geology, p. 13.
[3] Mem. Geol. Surv. India, Vol. V, p. 349.
[4] "Manual of Geology of India," Pl. II, figs. 8, 8a.
[5] "Sitzungsb. d. k. Akad. Wien.," Vol. XLV, p. 372, and figure.
[6] Mem. Geol. Surv. India, Vol. V, p. 64.

Trias (Muschelkalk and Bunter) being absent. Subsequently, however, Stoliczka incidentally mentions[1] shales of lower Triassic age in Rupsu, and it may possibly be therefore that the Shargol shales (as I shall frequently style these rocks) are partly of lower Triassic age. As, however, they are unfossiliferous, and as more to the south, they overlie metamorphic Silurians, there is little doubt, both in Stoliczka's and my own opinion, that they are mainly Carboniferous, and they have accordingly been so colored in the map.

Dr. Stoliczka, as I have said, mentions the difficulty which he found in distinguishing the Tertiary from the Carboniferous shales, and it is not quite clear to me to which group he referred some shales to the east of Shargol, which I think are certainly the Carboniferous; he speaks of "lumps and patches of it (Trias limestone) sticking out of the *so-called* Tertiary shales," as if he thought, as I think, that the shales were not Tertiary. I incline to think that the limestone in these shales is mainly in the form of lenticular masses, interstratified with them, though some of them may be outlying masses of the Trias overlying the shales.

Before discussing further the south-easterly extension of the Shargol shales, I proceed to notice two sections taken from the northern border of these shales to the south. The first of these extends from the Kashmír and Ladák road near Múlbeck up the ravine known as Múlbeck Rúng. Leaving the Kargil river, we first cross the blue limestone corresponding to the Shargol *Megalodon* beds, which has a southerly dip. These rocks are succeeded for a distance of about 3 miles by alternations of hard and massive white, green, and purple slates, with sandstones and limestones, the whole series being much folded, and its thickness difficult to estimate; these slaty rocks are much like those of the Trias of Tilel.[2] The slaty rocks seem to be succeeded by a great thickness of nearly horizontal strata of white dolomites and blue limestones, like those occurring in a similar position in Tilel, as described in my paper quoted above, and apparently corresponding to the higher part of the Trias of Drás (Para limestone); the slates between the *Megalodon* beds and the dolomites being much thicker than the intermediate (limestone and shale) beds at Drás. The dolomitic rocks continue across the ridge at the head of Múlbeck Rúng in a rolling series to the north of Gonpa Láma Serai, where they were noticed by Stoliczka (Rangdum Gonpa),[3] and are apparently faulted against the Silurians of the Drás series. Stoliczka merely noticed these strata from a distance, but speaks of them as "secondary deposits, undoubtedly of different formations." As I have said, I think, their highest beds are the topmost Trias (Para), and the series is undoubtedly the same as that which I have included in the Trias in Tilel and the Zoji-Lá.

The second section runs southward from the village of Hiniskot, on the Kashmír and Ladák road, across the Kangi-Lá. At Hiniskot itself we find cliffs of nearly vertical blue and buff limestones, corresponding to the Shargol *Megalodon gryphoides* beds, with a few slaty beds; these rocks continue in a rolled and much bent series till within some 2 miles of the village of Kangi, where we cross a synclinal axis in bright colored shaly slates, again underlaid by the

[1] Mem. Geol. Surv. India, Vol. V, p. 345.
[2] Rec. Geol. Surv. India, Vol. XII, p. 21.
[3] Mem. Geol. Surv. India, Vol. V, p. 347.

lower limestones nearer and at the village. The limestones seem here to form an anticlinal, overlaid again to the south by the colored slates, with one thick band of soft and dark colored shales, containing large ferruginous concretions. Higher up the Kangi stream, we find the slates extending as far as the village of Ampaltan, where we find them gradually succeeded by blue limestones, and these again by buff dolomites. These dolomites continue in a rolling series across the Kangi-Lá to the Silurian slates of Rundum, where they were colored in an unpublished map of Stoliczka's as Trias. This section is not very clear; the beds on the north are, I think, certainly the Lilang, and the southern dolomite the Para limestone; if this be so and the section correct, the intermediate slates must also be part of the Trias; they resemble the similarly placed rocks of Tilel. The thin band of black crumbly shales at Kangi with concretions makes a curious approach in mineralogical structure to the Spiti shales as described by Stoliczka: the other rocks do not, however, agree with the other Spiti Jurassics.

It may be noticed that at and below the village of Kangi, there occur in the bed of the stream numerous pebbles of a crystalline trap, with a rust colored weathering; these pebbles have been derived from a mass of trap occurring on snowy peaks, D 24 and D 25, to the eastward, to which I shall have occasion to refer subsequently.

Returning to the Shargol Carboniferous shales, we find them continued, as we have seen from Dr. Stoliczka's notes, to the eastward along the line of the Kashmír and Ladák road: north of Kárbu a few small patches of Triassic slates and limestones are found resting on the shales, and the latter are a good deal mixed with the Tertiary serpentine trap, especially near the nummulitic zone: these shales were traced by Stoliczka and myself, as noticed above, to Lámá-Yuru. Crossing the stream at Kárbu and proceeding in a north-easterly direction, we find the Carboniferous shales underlaid by slaty rocks, green, red, and black in color, which form the summit of the ridge on which Nindam station is situated. Among these lower slates Dr. Stoliczka[1] recognised the green (Silurian) rock of Drás; these slates are much mixed up with the serpentine trap. At Lámá-Yuru the Carboniferous shales are underlaid by the same slate series as occurs near Kárbu, and some beds of sandstone, with a south-westerly dip. The same slate rocks mixed with ribband jaspideous rocks like those between Tilel and Drás, and with the slaty sandy (trappoid of Stoliczka) rocks of the Drás river and the Pangong lake, occur in a descending series in the gorge leading from Láma-Yuru to the Indus. These rocks are, however, so intimately mixed up with the Tertiary trap, that it is exceedingly difficult to map them with any accuracy. To the eastward I have traced these slaty rocks to the village of Wanla, where they again underlie the Shargol Carboniferous rocks. Dr. Stoliczka says[1] that the colored shales and slates underlying the brown carbonaceous (Carboniferous) shales of Láma-Yuru are the representatives of his Múth and Bhabeh series (upper and lower Silurian): he further thinks there are traces of syenite (central gneiss(?)) underlying these slates, though I did not observe them myself. Near the Indus the Silurian slates are cut off by the Tertiary trap. From the mineralogical composition of the rocks in the Láma-Yuru gorge, they

[1] Geology, 2nd Yarkand Mission, p. 13.

appear to me to be certainly the same as the slate series of Kashmír, Tilel, Drás, the Pangong Lake, and Chúng-Chenmo.

From the Fotú-Lá the Carboniferous band extends in a south-easterly direction, its northern boundary running through Wanla, and thence slightly north of the road across the Choki-Lá to the Zánskár river, where I shall take it up subsequently. The southern boundary runs near the village of Panjíla, and thence in a south-easterly direction: near the village of Urchi there is a small synclinal in the lower shale-series, occupied by a patch of the bright-colored Triassic slates and limestones. Near Wanla a large proportion of blue limestone occurs in the lower Carboniferous shales, which is not unfrequently crowded with *Encrinites.* Iron also occurs in these rocks, and is worked in small quantities. To the south-east of Wanla, the Carboniferous strata consist of black flaggy slates, which, however, weather to the usual light-brown color, by which character they are readily distinguished from the older Láma-Yuru slates, which always weather black.

Close to Wanla there occurs a wide dyke of the Tertiary trap running in among the Palæozoics, which requires a moment's notice. On the south side of this dyke, between it and the Carboniferous shales, there occurs a considerable thickness of coarse vertical conglomerate, a good deal altered by the trap, and containing pebbles of the Trias limestone, and of the crystalline trap, already noticed as forming peaks Nos. D. 24 and 25. I cannot say whether or no this conglomerate corresponds to the higher Tertiary conglomerate near Gía; but since it has been jammed in between the trap and the Palæozoics in vertical beds, it affords the important piece of evidence that it is older than the trap, and that consequently the crystalline trap within the Triassic area is older than, and was denuded at the time of, the formation of the basaltic trap of the Indus.

A section through the secondary rock-series from the village of Panjíla, south of Láma-Yuru, to Yelchang bridge, on the Zánskár river, gives the following series of rocks. Leaving the shaly Carboniferous rocks near Panjíla, we find the overlying Trias at first consisting of hard purple and green slates, which are nearly vertical, mixed with some calcareous and limestone bands: these are succeeded by softer and brighter-colored slates, like those of Kangi; while shortly below the village of Hanúpatta (Hunúpatta), we come upon blue limestones with a lower southerly dip. From Hanúpatta to the Sirsa Lá there is a succession of blue limestones and white dolomites, with a few slates, which form a rolling synclinal, the underlying poikilitic slates again appearing beneath the limestones at the pass itself.

These limestones and dolomites appear to me to be the Para limestones, and they contain sections of fossils which appear to be those of *Dicerocardium himalayense*, characteristic of this band. This being so, the underlying slaty rocks must be the Lilang series, the limestones of Shargol being represented by these slates; this section confirms the Triassic age of the rocks in the Kangi section.

From the Sirsa Lá to the village of Phatoksir and thence across the Shingi

(or Shingo, or Singhi) Lá[1] to Yelchang on the Zánskár river, there is a continuous succession of the same limestones and shales. For want of supplies I was unable to continue my journey beyond Yelchang, but Triassic (Para) dolomitic limestone extended as far as I could see up the Zánskár valley. According to Dr. Stoliczka[2] the Zánskár valley near Zangla consists on either side of contorted Triassic limestone (Lilang ?) overlaid by the darker Para limestone on the higher ranges. To the south-east of Zangla near Niri-Sumdo (Niri-Chu), at the Shapadok-Lá, and the Saiji Lá, lower Tagling limestone (lower Lias) overlies the Para limestone; these are in turn overlaid by Spiti shales in small patches (the occurrence of the latter is roughly indicated on the map by yellow patches, while the lower Tagling is included in the sienna). I have no doubt but that the Trias of Yelchang is continuous with that of Zangla, with patches of Jurassic rocks occurring on the higher hills. I may observe that to one who like myself did not give the local names to the different limestones of the great Trias-Jura of this district (for, as in America, the Trias and Jura are one great rock series), it is exceedingly difficult to recognise these palæontologically different but mineralogically very similar limestones. General Cunningham[3] observes that limestones are found continuously across Zánskár from the Shinghi-Lá to the Láchi-Long-Lá, on the Ladák and Kulu road, where, as will be noticed below, the Trias seems to continue across Zánskár. I therefore conclude that the Triassic and lower Jurassic rocks form, with small exceptions, the whole of the central part of the great limestone ellipse of Zánskár.

Near the village of Thonde, in Zánskár, Dr. Stoliczka says[4] that "the Triassic beds are separated from the Silurian sandstones by a dark band of a greenstone-like rock, which I presume to be Carboniferous." These latter rocks have been provisionally so colored on the map, as there is a strong presumption from their position that they are rightly referred to that formation.

The trap occurring on peaks D. 24 and 25 must be post-Triassic age, though, from the amount of snow, I could not examine it closely *in situ*. It is distinguished from the Shargol trap by its more crystalline structure, and by the peculiar rusty brown weathering.

Reverting once again to the presumed Carboniferous rocks, which we have already traced as far as the village of Wanla, we find that from this point they continue across the Choki-Lá down to the Zánskár river, near the village of Chiling; thence their northern boundary is continuous with the southern boundary of the Tertiaries, which we have already traced. From Wanla to a

[1] Dr. Thomson is said to have brought nummulites from this pass (Mem. Geol. Surv. of India Vol. V, p. 354); this seems to have arisen from confusing this pass with the one to the north-east of the village of Shingo near Kio, which is often called Shingi-La, and under which name Dr. Stoliczka alludes to it when he found nummulites on it (sup. cit., p. 344); it is rather strange that the similarity of the two names did not strike Dr. Stoliczka when he wrote his paper. This error is repeated on page 14 of the Geology of the Second Yarkand Mission. Mr. Medlicott (Man. Geol. of India, p. 644) pointed out the probable error.

[2] Mem., Geol. Surv. of India, Vol. V, p. 246.

[3] "Ladak," p. 57.

[4] Mem., Geol. Surv. of India, Vol. V, p. 346.

long distance up the Markha river these rocks have a general south-westerly dip, and form a band of very uniform breadth to the north of the Trias. Near Kio, the lowest beds of the Carboniferous series which are exposed, are nearly vertical, and consist of blue-black limestone, traversed by veins of yellow quartz. Nearer Kio itself, the south-westerly dip becomes flatter, and the limestone is overlaid by brown shales and blue slates, with many bands of white and yellow quartz: many of the slates contain bands of carbonaceous matter, and are not unfrequently studded with small crystals of pyrite.[1] On the Markha river, a little below Kio, the yellow quartz is in great force, and gold-washing is carried on to a considerable extent in the detritus from these quartz-reefs. At Kio and in the neighbourhood, stems of *Encrinites* are of very common occurrence in the Carboniferous limestones, and at that place I obtained a coral closely allied to *Cyathophyllum*. To the south-east of Kio the mineralogical composition of the presumed Carboniferous rocks has the same general characters as those described above; the relative development of the limestones and shales is, however, locally very variable.

In noticing these rocks at Kio, Dr. Stoliczka observes:[2] "The nummulitic rocks are suddenly replaced by slates and carbonaceous limestones full of crinoid stems, which appear to be of Carboniferous age. All the way up from Kew (Kio) to the head of the Markha valley, nothing but these carbonaceous crumbly slates occur." No fossils were found in these rocks, and Dr. Stoliczka adds that there were probably representatives of the Silurian and Carboniferous among them. The slates of Kio are frequently full of small cubical crystals of pyrite. To the north-west, as we have seen, these rocks are continuous with the Shargol shales which we have classed as Carboniferous. To the south-west of Tso Moriri, I have traced this band into a series of slates noticed by Dr. Stoliczka,[3] who observes that "these slates can only belong to the Kúling (Carboniferous) series, being perfectly identical with the rocks of this (series) in mineralogical characters and geological position, underlying the Lilang limestone."

There is, therefore, every presumption of the whole of the blue bands on the map being of Carboniferous age.

To the south-east of the valley of the Markha river the band of Carboniferous rocks continues along the southern border of the Eocenes, till it finally dies out on the upper Indus, between the latter and the gneiss of Rupsu. On the Gía river the Carboniferous rocks have undergone great contortions; they consist at Gía itself of brown weathering shales mixed with blue quartzitic limestones generally in lenticular masses; the shales are often quartzitic and carbonaceous and dip generally towards the Tertiaries, which they frequently much resemble.

To the southward of Gía we have at first a folded series of these rocks, which, further to the south, is underlaid by hard blue slates and micaceous sandstones, similar in structure and position to the Silurians of Láma-Yuru. Near

[1] The composition of the Carboniferous series here is closely analogous to that of the Kiol series in the outer hills, which confirms my opinion as to the Carboniferous age of the latter (see Rec. Geol. Surv. of India, Vol. IX, p. 160).

[2] Mem. Geol. Surv. India, Vol. V, p. 344.

[3] *Ibid.*, p. 348.

the Tagalúng-Lá and to the west of Ralla St. there occurs a synclinal in these rocks, consisting of the Carboniferous shales, quartz and limestones; near the pass large lenticular masses of pure white saccharoid quartzite, like that of the Pangong Lake, occur in these rocks. In the centre of this synclinal there occur beds of dolomitic limestones, mixed with some reddish shales, which are probably the Lilang series. Dr. Stoliczka, in his notes on the Tagalúng-Lá[1] (Taglang), does not notice these limestone rocks, and speaks of all the rocks as belonging to the metamorphic series.

The Carboniferous rocks in the Tagalung synclinal are underlaid to the south by the slaty and sandy Silurians. Lower down the Zára river there is an anticlinal, to the south of which the slates gradually assume a gneissoid character, the crystalline rocks occurring as lenticular masses among the slates.

This gneiss and slates are again overlaid conformably to the south-west by the carboniferous rocks of Kio. The gneiss and slate series can be traced to the north-west nearly to the Markha river, where they form a wedge-shaped mass intruding between the Carboniferous rocks, which here split to receive them. To the south-east the slates and gneiss, which form one series, have been traced by Dr. Stoliczka to the south of the Indus, and across Rupsu to the south of Tso-Moriri and were classed by him as the equivalents of the Silurian. The gneiss is dark-colored, and very generally porphyritic, with large crystals, often 3 or 4 inches in length, of gray orthoclase. It is quite different in character from the white gneiss of the Kailás range, and when non-porphyritic is very like the altered Silurians of Tánkse. As the Rupsu slates and gneiss directly underlie strata which are certainly not newer than Carboniferous they must probably be of Silurian age, as suggested by Dr. Stoliczka, and consequently the equivalents of the slates of Drás and Tánkse. It will be noticed that the strike of the altered Rupsu Silurians is continuous with that of the unaltered Silurians of Láma Yuru, and the two probably belong to the same band.

To the south-west of the Silurians of Rupsu the Carboniferous rocks, which, as we have seen, split near the head of the Markha river, form a continuous band of nearly the same width, which I have traced to the south-east of the Kiang-Chú plain, whence the same band has been traced by Dr. Stoliczka in a south-easterly and southerly direction into Spiti, and which, as before said, to the south-west of Tso Moriri, underlies the Lilang limestone.

At Kiang-Chú the Carboniferous rocks consist of shales, frequently containing crystals of pyrite, like those of Kio, and alternating with large lenticular masses of blue quartziferous limestones; these are succeeded by banded limestones, alternating with highly carbonaceous shales. These shales continue for some distance in a V-shaped hollow up the valley leading to the Láchi-Long Lá; they are succeeded by blue, buff, and white limestones and dolomites which, with the occasional exceptions of small patches of carboniferous shales appearing beneath them in the valleys, continue to near Lingti. Near the top of the Láchi-Long pass there seems to be an anticlinal of Carboniferous shales underlying the dolomites. In these limestones and dolomites there are seen numerous sections of ***Megalodon***

[1] Mem. Geol. Surv. India, Vol. V., p. 343.

and *Dicerocardium*, and most of the rocks may be taken as the equivalents both of the Lilang and Para limestones:[1] fragments of a *Lima* are not uncommon; and corals and crinoids are extremely common in these rocks. The thickness of this dolomitic series is at least 3,000 feet near the Láchi-La. In the Lingti valley the Para limestone with *Dicerocardium* occupies the upper part of the hills, underlaid by the Lilang limestone; the rocks have here undergone immense contortions and foldings. To the south-west of Lingti the Triassic rocks are underlaid by blue and reddish shales, with white quartzites and blue limestones: from their position and composition I have little doubt but that they are mainly Carboniferous; patches of similar rocks, with *Productus* and *Spirifer*, were noticed by Dr. Stoliczka[2] to the south-east of Lingti (Tsárap valley), underlying the Lilang limestone near Lámaguru (Yuroo. Stoliczka). I have traced the Carboniferous and Triassic rocks a considerable distance to the north-west of Lingti, and they are doubtless continuous with the corresponding rocks near Zangla, mapped by Dr. Stoliczka, overlying the Silurians of Padam.

To the south-east of Lingti, Dr. Stoliczka[3] observes that above the Lilang limestone at the bottom of the valley, the greater part of the Tsárap valley consists of the Para limestone full of *Dicerocardium himalayense* and *Megalodon teiqueter*. The Para limestone in this district is of a light-blue color, with a marbling of white; it is very different from the white dolomites of the Drás river, which Dr. Stoliczka correlates with it; the Triassic rocks, however, appear to me to vary very considerably in composition. In the upper part of the Tsárap valley, according to Dr. Stoliczka, the higher hills consist of the lower Tagling limestone (lower Lias?) with *Terebratulæ* and *Rhynchonellæ*: the summit of the Pangpo-Lá consists also of the same limestone, while the higher ridges near the pass are capped with Spiti shales, and Gieumal sandstones (upper Jurassic); and fragments of the Chikkim (Cretaceous) limestone were also found in the neighbourhood; these rocks must apparently rest unconformably on the lower Tagling. To the north of the Pangpo-Lá the lower Tagling limestone, according to the same authority, forms the prevailing rock, underlaid for a short distance by the Para limestone, which appears to be greatly developed to the south-east. Near Khiang-Shísha the limestone belongs chiefly to the Lilang group, and

[1] There may probably be representatives of the lower Lias (lower Tagling) on some of the higher hills. On page 38 of volume XXII of the Quarterly Journal of the Geological Society, Mr. Davidson in describing some fossils collected by Colonel (then Captain) Godwin-Austen, mentions some Brachiopods, said to have been obtained in a light gray limestone "near Lacholung-Lá, north side, in the Suru country in Thibet." In Suru there is no Lacholung-La that I am aware of, and I think the place referred to must be the Lachi-Long Lá in Rupsu. The said fossils are either Jurassic or Cretaceous, and if the above determination of locality be correct, rocks of one or other of these systems must occur probably on the higher peaks around the Lachi-Long. The crest of the pass shows carbonaceous shales in an anticlinal which I think are certainly Carboniferous, and undoubted Trias rocks with *Megalodon* occur near by. If the patches of newer rocks exist near the pass, they would be on the strike of similar rocks noticed by Stoliczka on the heights above the Pangpo Lá.

[2] Mem. Geo. Surv. of India, Vol. V, p. 342.

[3] *Ibid.*—I was prevented by want of supplies from examining this country more closely.

is underlaid to the north-east, as noticed above, by the Carboniferous series, which again overlies the metamorphic Silurians of Rupsu.

In the map accompanying this paper the whole of the great limestone series above the Carboniferous, from the Lilang to the lower Tagling limestone, is colored of one tint, and may be called the Trias-Jura. Owing to the variations in the mineralogical characters of these rocks, to the general absence of fossils, to the enormous contortions which the rocks have undergone, and lastly, but not leastly, owing to the difficult nature of the ground, and the short time that one can spend in these inhospitable regions, it would be quite impossible to map the different outcrops of each of the separate groups. Near Lingti the rocks, which I consider as the Carboniferous, are underlaid by a great thickness of hard dark slates, quartzites, sandstones, jaspideous rocks, and the slaty-sandy trappoid rock of the Drás river. These rocks which may be traced across the Báralácha pass into Lahúl, I have also traced to the north-west into the Silurians of Padam and Zangla which rest upon the gneiss of the Zánskár range, and continue thence to join the slaty rocks of Drás, to the south-east these rocks are continuous with the fossiliferous Silurians of the Bhabeh pass and Múth.

Speaking of the great slate series at Lingti, Dr. Stoliczka observes[1], "Any one acquainted with the rocks of the Múth series in the Pín valley would find all these represented here," and speaks of the lower beds as corresponding with his Bhabeh group (lower Silurian).

Near Lingti the rocks are very horizontal, and the summits of the ranges are capped by shales, blue limestones, and white and purple quartzites and sandstones. Some of these limestones and sandstones seem to me to be probably of Carboniferous age, as they correspond to similar rocks at Pángong, and also to rock specimens in the Indian Museum from the Carboniferous series near Múth: the lower beds are probably, however, upper Silurian, since Dr. Stoliczka found a fragment of an *Orthis* in similar rocks to the west of the Báralácha (Baralatse) pass. The upper Silurians and Carboniferous (Múth and Kuling) in this district and Spiti (as I judge from rock-specimens in the Indian Museum collected by Dr. Stoliczka) seem frequently to be very similar in mineral composition, and it requires a full series of fossils to separate them distinctly. The blue patches on the map in this district must be considered as only approximately of Carboniferous age, they mainly serve to indicate the distribution of the light-colored quartzites and shales on the top of the older slates.

On the Bhága river, some miles below the village of Dárcha,[2] the Silurian slate series is underlaid conformably by distinctly stratified granitoid gneiss [3] which Dr. Stoliczka recognised as his so-called "central gneiss," and which, he says, underlies undoubted Silurians.

This gneiss forms the southern limit of the Ladák and Zánskár basin, but may be treated of here. To the north-west this gneiss is continuous, with the great mass of gneiss of the Zánskár range and Suru, which I described in a

[1] Mem. Geol. Surv. of India, Vol. V, p. 341.

[2] For this area see my map published in the eleventh volume of the "Records," p. 85.

[3] In a previous paper (Rec. Geol. Surv. India, Vol. XI, p. 55) following Dr. Stoliczka, this gneiss was stated to occur at Dárcha itself.

former paper,[1] but which I could not then certainly determine to be the "central" gneiss; according to Stoliczka's identification, this gneiss may now be considered as of pre-Silurian age, and in this district as having been altered out of an older and conformable slate-series, unless some hidden unconformity should exist.

The rocks on the southern flanks of this gneiss ridge will be treated of in the next section, and their general relations in the last section.

IV.—Rocks of South Lahúl and Kulu.

To the south of the gneiss ridge of Lahúl, we find an ascending series of slates, with a general south-westerly dip. Near the junction of the Chandra and Bhága rivers, we find blue limestones, with carbonaceous shales and a few pale sandstones, capping the slates in the angle between the two rivers. To the south a large mass of the same limestone and other rocks overlies the slates with a southerly dip, and appears to be itself again overlaid by the same slates. The limestones, on a more careful examination, are, however, seen to be folded back on themselves, and it appears probable that they form a synclinal, the slates on the southern side of the synclinal having been bent over and inverted on the limestones: from their physical characters there can be no doubt but that these limestones are the same as the limestones of North Lahúl,[2] which are probably partly upper Silurian and partly Carboniferous.

The Silurian slates of the Bhága and Chandra rivers I have previously traced[3] into Pángi to the north-west, and for some distance to the south-east. Near the village of Kokser on the Chandra there occurs, at the base of an anticlinal in the slate series, some very massive gneiss, which, I think, is in all probability the same as the central gneiss of North Lahúl. This gneiss is overlaid by alternations of gneiss, micaceous rocks and slates, most of which appear to pass directly into the slates underlying the higher limestone, and which would, therefore, seem to be altered Silurians. These rocks continue across the Rotang pass and down the Beás valley nearly to the town of Naggar. Some of the gneiss is very massive, and in many cases seems to overlie the slate-series; this, however, may be due to inversion, and it seems to me probable that some of this gneiss is "central" gneiss, while some has almost certainly been altered out of the overlying Silurian slates. The series is, however, so involved that I was not able to mark out any bands as of a fixed position.

To the south of Naggar we have generally slates and sandstones till we reach the infra-Krol and Krol groups of Mr. Medlicott near Bajoura, which have been already described by him,[4] and to which I shall, therefore, not refer on the present occasion.

[1] Rec. Geol. Surv. India, Vol. XI, p. 53.

[2] In a former paper (Rec. Geol. Surv. India, Vol. XI, p. 54) I thought from their apparently lying among the slates that these limestones formed part of the lower Silurian series.

[3] Rec. Geol. Surv. India, Vol. XI, p. 55.

[4] "Mem. Geol. Surv. India, Vol. III, pt. 2, p. 57.

V.—SUMMARY AND GENERAL CONCLUSIONS.

I now proceed to bring to notice some considerations regarding the general relations of the Ladák rocks to the rocks of the neighbouring Himalaya. In so doing I shall take the rocks in their geological sequence.

1. *The Tertiaries.*—These rocks have been sufficiently treated of in the section devoted to them. I have only to bring to notice the very remarkable resemblance in mineralogical character which exists between these rocks and the corresponding Eocene (Subáthu) rocks of the outer Himalaya. We have good reason to believe that these two groups of rocks were deposited in perfectly distinct basins, and we can, therefore, only conclude that this resemblance in mineralogical characters is due to the Eocenes of both regions having been deposited under very similar physical conditions, and to their materials having been derived from the disintegration of very similar rocks.[1]

2. *The Cretaceous.*—As only small patches of cretaceous rocks occur in the area under consideration, which I have not seen myself, I have no remarks to make concerning them.

3. *The Trias-Jura and Carboniferous.*—The Triassic and Jurassic rocks, with which the Carboniferous are often closely associated, in this area of the Himalaya occupy three main elliptical basins, *viz.*, that of Drás and Tilel, that of Zánskár and Ladák, and that of Kashmír proper, while other outlying masses of the same rocks occur in the Cháng-Chenmo valley, and probably (though the correlation is not certain) in the outer hills. In the western part of the area the Trias and the Carboniferous seem to be very closely connected with each other, and (especially in Kashmír) it is frequently very difficult to distinguish between the two, and, as I have said in my last paper, some of the rocks mapped as Carboniferous may really be Trias, although as the upper beds are unfossiliferous, and of the same mineral character as the lower, except occasionally, it is difficult to distinguish them. No traces of the Jurassic rocks have been noticed in Kashmír or Tilel.

In the Zánskár and Ladák basin, the Carboniferous is very distinct from the Trias, and according to Dr. Stoliczka, there is sometimes local unconformity between the former and the upper groups of the latter: it may be that the lower Trias is represented in Kashmír and Tilel, which would cause the greater union of the Carboniferous and Trias in those districts.

In Spiti Jurassic rocks are extremely prevalent, while, as far as I can judge, they appear to become less and less developed as we approach the north-western extremity of the Zánskár and Ladák basin; Cretaceous rocks are also well developed at the south-eastern extremity of this basin, and are represented only by patches here and there towards the central part. It would thus appear that in the north-western portion of our area the rocks of these basins are older than many of those to the south-east, there being a gradual increase in the proportion of Trias, Jura, and Cretaceous as we travel from Kashmír to Spiti.

The Trias-Jura in these basins is generally characterised by the great pre-

[1] It may possibly be that the Indus and outer Himalayan Eocenes were deposited in two arms of a sea connecting the two to the westward.

valence of whitish dolomites and dolomitic limestones, often locally alternating with poikilitic shales and slates, the relative development of which varies considerably in different districts. The Zoji-Lá slates[1] still remain a puzzle to me, as I cannot correlate them with any of the Ladák rocks, though I still think those nearest the Trias are newer than it, from the evidence of the Panjtarni section. Some of the metamorphic rocks in the centre of the ellipse must, however, I think, be older, though it is extremely puzzling to imagine how they are related to the other rocks, and the country is so rugged and difficult of access that it will be very hard to come to any precise conclusion.

In most parts of Zánskár, Ladák, and Tilel the rocks above the Carboniferous form one continuous geological series, characterised by the great prevalence of dolomites and limestones; except towards Spiti, fossils are very rare, and the whole naturally presents a combined Trias-Jura, as in America. Had no fossils been found in any of these strata, and were geological nomenclature to have originated in this district, the whole rock-series would be classed as one great system.

The great geological unity in many districts of the whole series, from the Carboniferous to the Jura, is a point on which I desire to lay great stress, as indicating the different results arrived at by purely stratigraphical, on the one hand and purely palæontological geology, on the other.

The Carboniferous rocks vary considerably in mineralogical composition: in many parts of the valley of Kashmír they consist of pure blue limestones, full of characteristic fossils; while in other districts of Kashmír and elsewhere, they consist mainly of alternations of shales, slates, and limestones, very frequently containing crinoids and carbonaceous matter, and at other times quite unfossiliferous.

From the occurrence of the Carboniferous and Triassic series generally in synclinal ellipses, with their longer axes coincident with the normal strike of the Himalayan rocks, together with the generally uniform mineralogical character of the Trias, I think it almost certain that these rocks once extended continuously over the whole area.[2] It may be that from the varying composition of the Carboniferous series these rocks were deposited in a shallower sea than those of the Trias.

From the occurrence of no rocks newer than the Cretaceous, and from the vast amount of denudation which must have taken place to remove the Jura and Trias from such large areas, I am greatly inclined to believe that, with the exception of the Indus valley and a band along the outer hills, this area has been land continuously since the Cretaceous epoch.

During the past season I have for the first time had an opportunity of seeing the Krol limestone, and desire to add a few words to my previous conclusions regarding it. It will be remembered that I have described a band of limestone and other rocks running along the outer foot of the Pír Panjál range[3] under

[1] Rec. Geol. Surv. India, Vol. XII, p. 17.

[2] I desire to retract an opinion previously expressed (Rec. Geol. Surv. India, Vol. XI, p. 48) that the Carboniferous rocks were deposited in separate basins.

[3] Rec. Geol. Surv. India, Vol. IX, p. 160.

the name of the Kiol series, which I have regarded as the representative of the Carboniferous. This limestone band I have also considered to be almost certainly, from its composition and position, to be the equivalent of the inverted band of Krol limestone running along the foot of the lower Himalaya in the Simla district, and these opinions I still hold to.

I at the same time considered that the whole of the limestones capping the slates in the Simla district, which are presumed to be the same as the Krol of the foot of the mountains, to be also of Carboniferous age. An inspection of these Simla limestones, with their underlying Blaini rocks and Simla slates, has shown me that they agree so closely with the Carboniferous and Silurians of Lahúl, that I am most strongly confirmed in my opinion that the slates are of Silurian, and at all events the lower limestones, of Carboniferous age. Mr. Medlicott,[1] in describing the infra-Krol rocks, notices in them the great prevalence of a carbonaceous element, and in the overlying Krol, of limestones underlain by quartzitic sandstones. In both these characters the rocks in question agree exactly with the presumably Carboniferous rocks of North Lahúl.

The Krol limestone is, however, so much thicker than the Carboniferous of Lahúl and Ladák, that I now incline to the opinion that the upper part of it is probably the representative of the Trias of those districts. The characteristic dolomite is, however, wanting, and in the absence of fossils we have no means of sub-dividing the Krol. I have already stated my opinion that the enormously thick limestones of Kashmír may be the representatives of both Carboniferous and Trias, and I now extend this opinion to the Simla Krol limestone and the Great limestone of the outer hills. In Kashmír, as I have noticed above, the Carboniferous and Triassic series are generally so closely related that it is often difficult to draw any hard and fast boundary between them, and since they often vary locally to a very considerable extent in mineralogical composition, there would be nothing extraordinary in their being still more indistinguishably blended together in a region some distance away. According to this view the infra-Krol carbonaceous shales would probably be Carboniferous (with which rocks in Ladák they correspond in composition to a considerable extent), and both upper and lower Trias and upper Carboniferous may be represented in the Krol. Some of the shales in the Kiol are much like those of the infra-Krol.

4. *The Silurian.*—The past season's work has rendered an important contribution to the geology of this part of the Himalaya, in confirming the conclusions previously arrived at as to the Silurian age of the great slate series. The key to this problem lies in the Spiti district, where these slates contain Silurian fossils, and underlie conformably the Carbo-Triassic rock series, and overlie the "central" gneiss. From Spiti these Silurian slates may be traced through Zánskár to Drás and thence to Tilel,[2] where I have elsewhere shown that these slates are the equivalents of those of the Kashmír valley, the Pír Panjál and the Kishtwar district. The slates of Pángi,[3] from their relations to the gneiss, must in all probability be of contemporaneous age.

[1] Manual of Geology of India, p. 600.
[2] Rec. Geol. Surv. India, Vol. XII, p. 20.
[3] *Ibid.*, Vol. XI, p. 54.

The slates of Láma-Yuru, Tánkse, the Pangong Lake, and the Cháng-Chenmo valley, from their similarity in mineral composition to those of the Drás river are likewise inferred to be of the same age, which inference is strengthened by the slates of Pangong, which can be traced into connection with those of Tánkse, underlying strata of presumed Carboniferous age.

The slates and gneiss of Rupsu, which likewise underlie Carboniferous strata, must also be placed on the same horizon.

5. *The lower gneiss.*—In the foregoing sketch it has been shown that the gneiss of the Kailás range conformably underlies a large thickness of slates, which seem to correspond approximately in position to the Silurian: following the same system of nomenclature, such gneiss may be termed Cambrian gneiss as consisting of a distinct geological formation. It has further been shown on a previous occasion,[1] that the gneiss of the Zánskár range and of Kashmír is similarly situated in regard to the slates of those districts, which are also classed as Silurian; there is, therefore, considerable *primâ facie* evidence that all this gneiss is contemporaneous.

It now remains to consider whether any or all of such gneiss is equivalent to the "central" gneiss of Dr. Stoliczka. It appears from the sections of the gneiss and Silurians in the Spiti district, where the "central gneiss" was first named, that that gneiss is unconformable to the Bhabeh Silurians, though this is not clearly stated in the text: if this be true, the central gneiss existed as such at the time of deposition of the slates. Dr. Stoliczka, however, himself recognised the gneiss of North Lahúl as "central gneiss,"[2] and also suggested that some of the gneiss of the Zánskár range to the south of Padam and Suru belonged to the same formation. No evidence of unconformity can be seen in this section.

It has been noticed in my paper on the gneiss of the Zánskár range[3] that possibly some portion of the latter was gneiss at the time of the deposition of the Silurians; and it was suggested that such gneiss might be the equivalent of the "central gneiss." It was also shown on that hypothesis that the gneiss in North Lahúl identified by Dr. Stoliczka as "central gneiss," must, if rightly identified, be unconformable to the overlying Silurians. But until the conformity or unconformity of the central gneiss is elsewhere settled, it cannot be settled here.

It, therefore, seems pretty clear that the "central" gneiss is represented in the Zánskár range, but, as I have said in my above quoted paper, how much or how little of such gneiss is "central gneiss" cannot be determined. Similarly, in the Kailás range, it is probable, in my opinion, that the lower massive gneiss may be the central gneiss, and therefore unconformable to the higher gneiss beds, if the central gneiss is always so: how much or how little of the central gneiss occurs there I cannot possibly say. As in my other maps, the whole of the gneiss underlying the Silurian slate series has been colored the same tint, and has been called central gneiss; this gneiss must, however, include both the gneiss conformable and that unconformable to the slates (if there be such) and might rather have been called Cambrian and central gneiss.

[1] Rec. Geol. Surv. India, Vol. XI, p. 59.
[2] Mem. Geol. Surv. India, Vol. V, p. 341. Rec. Geol. Surv. India, Vol. XI, p. 59.
[3] Rec. Geol. Surv. India, Vol. XI, p. 60.

The enormous thickness of slates overlying the gneiss in Pángi and in Cháng-Chenmo appears to me to be at least as thick as the slates in the Bhabeh section. It would, therefore, seem on the unconformity hypothesis that such gneiss as conformably underlies the Silurians, and which I call Cambrian gneiss, is unrepresented in that section. How thick or how thin this conformable Cambrian gneiss may be, or whether it is the same as the central gneiss, I cannot say. In other places, where the slate series is thinner, some of the great underlying gneiss series, as I have said in my previous papers, may correspond to part of the Silurians of the Bhabeh section.

I have already stated that the gneiss of the Kailás range dips to the north, and that the oldest beds are consequently exposed along the valley of the Indus: and I have also shown that when the Palæozoic rocks appear along the valley of the Indus beneath the Tertiaries that they are either of Carboniferous or upper Silurian age. We may, therefore, pretty safely conclude that the southern boundary of the Kailás gneiss is a faulted one.

Dr. Stoliczka did not apparently observe the relations of the gneiss of the Kailás range to the overlying slates, and, apparently identifying it with the gneiss of Rupsu, came to the conclusion that all the Ladák gneiss was of Silurian age, a view which in a previous paper[1] I accordingly adopted, before I had personally examined the relations of the rocks *in situ*. This view was, of course, adopted in the "Manual of the Geology of India[2]." With regard to the objection that the Ladák gneiss differs in composition from the central gneiss, I may state that I have elsewhere[3] shown that the gneiss of Drás is frequently granitic in composition, and that there is also a great variety in the composition of the Ladák gneiss, granitic gneiss being not uncommon among the syenitic varieties. The presence of veins of albite granite in the gneiss of the Kailás range in the Chimray valley is another point, as far as it goes, connecting this gneiss with that to the south.

A general survey of the map from north to south shows a series of gneissic ridges (Dhaoladhar, Pir-Panjál, Zánskár, and Kailás) running from south-east to north-west, the hollows between which ridges are sometimes occupied by normally overlying Silurians, and sometimes by newer rocks, which have been faulted down.

ADDITIONAL OBSERVATIONS.

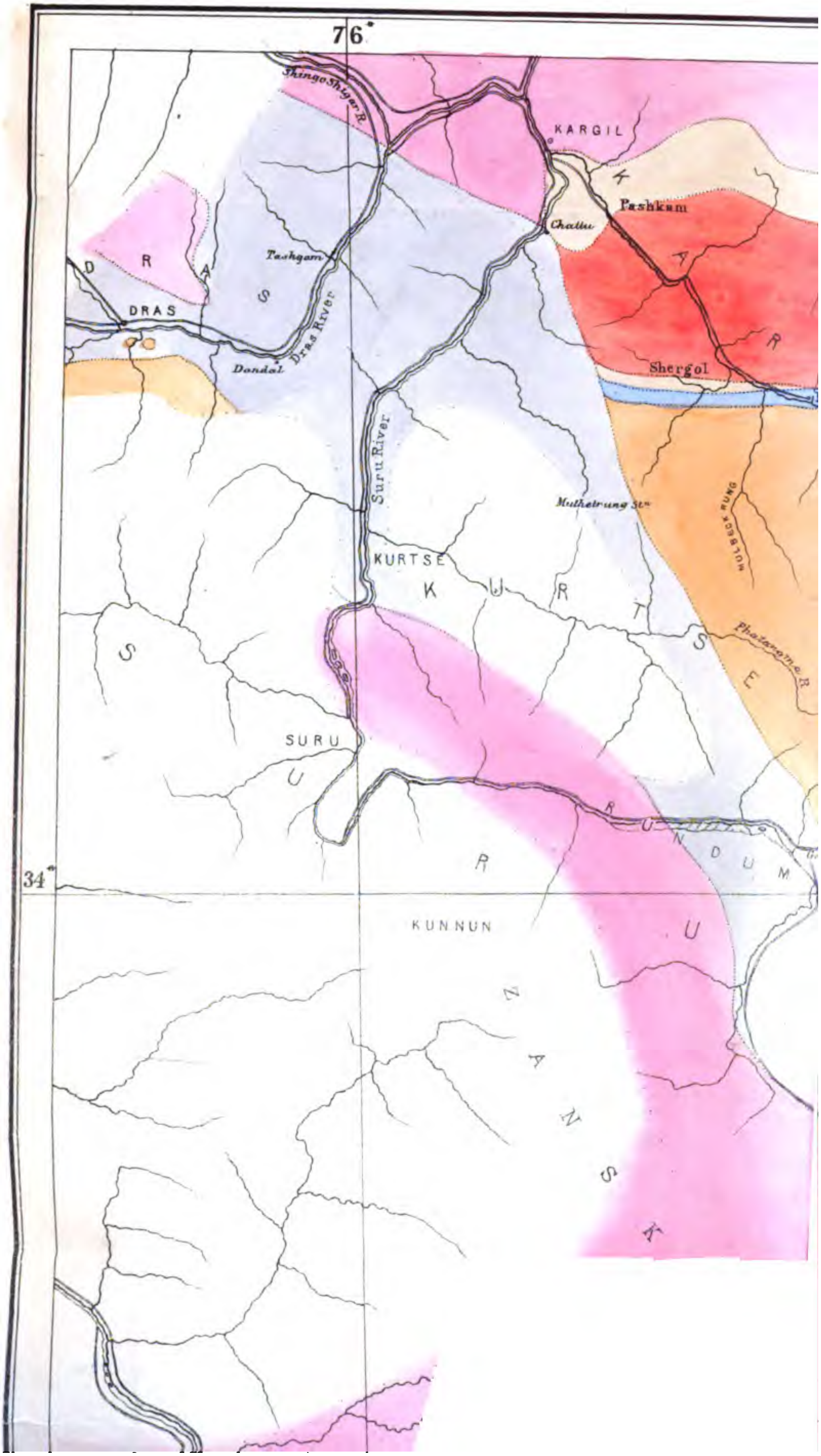
In conclusion, I may add, that I have lately found a series of Carboniferous fossils in the Indian Museum, which were sent by Mr. F. Drew, and were obtained in the Wardwan valley, a little above the village of Súkness.[4] These fossils comprehend the characteristic Carboniferous *Fenestellæ*, *Producti*, and *Spirifers*, and occur in a black shale like that of Eishmakám in the Lidar valley of Kashmír. Some dolomitic limestones, also sent by Mr. Drew from a point still higher up the Wardwan, appear to belong to the Trias.

[1] Rec. Geol. Surv. India, Vol. XI, p. 59.

[2] Page 653.

[3] Rec. Geol. Surv. India, Vol. XII, p. 19.

[4] See map and paper by myself in "Records," Vol. XI. Súkness is about 16 miles north of Inshin.


76°
Shingo Shigar R.
KARGIL
Pashkam
Chattu
DRAS
Tashgam
Dras River
Dondal
Shergol
Suru River
KURTSE
SURU
KUNNUN
34°

Near Avantipúr in Kashmír, I found this season some Carboniferous fossils in the higher beds of the trappoid rocks, showing that some of these extend upwards into the Carboniferous.

TEETH OF FOSSIL FISHES FROM RAMRI ISLAND AND THE PUNJAB, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

DIODON.

Among the collection of fossils transferred to the Indian Museum from the Asiatic Society of Bengal, there occurs the palatal tooth of a fish, said to have been obtained from Rámri (Ramree) Island, off the Arakan Coast, by Captain Foley. This tooth consists of a series of horizontal and oval plates, lying one above another. Each plate is divided by a vertical line into symmetrical lateral portions, and the lowest plate seems to have lately separated from another inferior plate. Superiorly the tooth is bevelled away by an oblique and concave surface of detrition, exhibiting a section of the edges of each of the component plates. The longer diameter of the lowest plate is 1·2 inches, and the shorter 0·7 inch. The above description will clearly show that the tooth belongs to the genus *Diodon.*

A precisely similar tooth was obtained by Mr. Wood-Mason at Port Blair, in the Andamans, in a sandstone rock.

With regard to the age of the deposits from which these teeth were obtained, it appears from Mr. Mallet's paper on the "Mud Volcanoes of Rámri and Cheduba,[1]" that the author considers the Rámri rocks to be of Nummulitic age: Mr. Blanford, in the "Manual of the Geology of India,[2]" also classes most of the Rámri rocks as Nummulitic, but thinks that some on the eastern side of the island may be of cretaceous age. The rocks of Port Blair, according to Mr. Blanford,[3] are similar to those of the Arakan Yoma, which (p. 713) are also Cretaceous and Nummulitic. From the majority of the rocks in Rámri Island being of Nummulitic age, and from *Diodon* not being known elsewhere below the Eocene, I think it most probable that the fossil teeth are of Nummulitic age.

The living Globe Fishes, according to Dr. Gray,[4] are inhabitants of all the warmer seas, and comprise four species, of which *D. hystrix* alone inhabits the Indian Ocean. Of the latter species I have examined a small specimen, some 10 inches in length. In that specimen the teeth are, of course, much smaller than our fossil specimen, but as the living species grows to a very large size, no distinction can be drawn on these grounds. In *D. hystrix*, however, the worn surface of both upper and lower teeth is quite flat, while in the fossil

[1] Rec. Geol. Surv. of India, Vol. XI, p. 192.

[2] p. 717.

[3] *loc. cit.*, p. 733.

[4] Brit. Mus. Cat. of Fishes, Vol. VIII, p. 306.

tooth this surface is markedly concave. Owing to the difficulty of seeing the teeth in the jaw of *D. hystrix*, I could not institute any closer comparison. I have no opportunity of comparing the teeth of the three other living species with the fossil.

Of the fossil Diodons, *D. tenuispinus*, from the Eocene of Monte Bolca, is a small species,[1] while our fossil is a large one. *D. scillæ*,[2] from the Tertiaries of Southern Italy, seems to have the edges of the plates of the teeth crenulated. The teeth of *D. erinaceus*[3] seem to be unknown. The teeth of *D. vetus*, from America,[4] seem to have had triangular plates. A *Diodon* has been mentioned by Professor L. Adams[5] as occurring in the Miocene of Malta, but has not been specifically named.

Although I cannot be certain of the specific distinctness of the Rámri fossil tooth, I yet think, that as it seems to belong to a distinct species from the species now living in the Indian Ocean, and as it is very difficult to refer to specimens without distinct names, I shall do well if I provisionally call the fossil *Diodon foleyi*, after the discoverer of the Rámri specimen.

On page 35 of the 3rd part of the 1st volume of the IVth series of the "Palæontologia Indica," the Rámri tooth is referred to as of cretaceous age.

The occurrence of the fossil Diodon in the Eocenes around the Bay of Bengal, and the existence there of a living species, would seem to indicate that the genus has inhabited the Indian Ocean continuously since the Eocene.

CAPITODUS.

The genus *Capitodus* was made by Count Münster[6] for the reception of certain jaws and teeth of fishes from the Miocene of the Vienna basin. These fishes were furnished with palatal, and peculiarly flattened incisor teeth. Count Münster classed them among the Ganoids; but M. Agassiz[7] considered that they belonged to the Sparoid Teleosteans (Breams and Sea-Breams), which seems to be the more probable view. *Capitodus truncatus* has been subsequently described from the Miocene of upper Silesia.[8] I am not aware that any new species of the genus has been recorded since the original five species described by Münster. Some years ago, however, Mr. Wynne sent to the Indian Museum a fish-tooth from the beds overlying the nummulitic salt zone of Kohát, which by Dr. Feistmantel and myself has been determined to belong to the genus *Capitodus*. The tooth is one of the so-called incisor teeth, and has a broad, laterally expanded crown, the dentition of which is worn obliquely and concavely on the inner surface. The external surface is coated with hard shining enamel, and is convex laterally; the base of the crown is anchylosed to a bony pedicle, which must once

[1] Pictet: "Traité de Paléontologie," Vol. II, p. 123.

[2] *Ibid.*

[3] *Ibid.*

[4] Leidy: Pro. Acad. Nat. Sci., Philadelphia, Vol. VII, p. 397.

[5] Quar. Jour. Geol. Soc., Vol. XXXV, p. 529.

[6] Beitrage zur Petrefacten kunde, Bayreuth, 1839—46.

[7] Bronn: Index, Paléont. Nomenclator, p. 214.

[8] Roemer: "Geologie von Oberschlesien," Breslau, 1870, pl. XLVIII, fig. 4.

have joined the jaw. The width of the crown is 0·7 inch, and its height 0·4 inch.

The general form of the crown of this tooth, and its wear, is much like that of the incisor of *Capitodus truncatus*[1]; the crown is, however, proportionally much wider in the Indian than in the European tooth. The other European species have still narrower incisors. The Indian tooth belongs apparently to a distinct species, which I propose to name *C. indicus*.

The strata from which the tooth was obtained are probably of upper Eocene age. The genus *Capitodus* seems to be closely allied to the living Sparoid *Sargus*,[2] but is distinguished by its broader incisors. The Indian species carries the genus back to the upper Eocene.

NOTE ON THE FOSSIL GENERA *Nöggerathia*, STBG., *Nöggerathiopsis*, FSTM., AND *Rhiptozamites*, SCHMALH, IN PALÆOZOIC AND SECONDARY ROCKS OF EUROPE, ASIA, AND AUSTRALIA, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

In my Flora of the Talchir-Karharbari beds, I had occasion to notice what was then known regarding thé systematical position of the genus *Nöggerathia*, and also to show the reasons why I thought that certain leaves of the Indian coal beds, described as *Nöggerathia*, differ from this genus in the proper sense; I accordingly named them *Nöggerathiopsis*, leaving them with the *Cycadeaceæ*. At that time I could not refer to the Australian *Nöggerathia;* but later examination and comparison have shown that the Australian leaves, also called *Nöggerathia*, do not generically differ from the Indian *Nöggerathiopsis*, and have therefore to be also classed with this genus.

In India the leaves seem to represent one species only, with about one or two varieties; they are known from (*a*) The Talchir-Karharbai group, and (*b*) from the Raniganj-Kámthi group.

In Australia this genus is known to begin in the lower coal-measures (below the first marine fauna), from which I described one species as *Nöggerathiopsis prisca*. It is more numerous in the upper coal-measures (Newcastle beds), from which two species of *Nöggerathia* were described by Dana; they should now, of course, be classed with *Nöggerathiopsis*.

There is a close representative of this genus in the Siberian Jura, *i.e.*, in the Kusnezk basin of the Altai, and on the Lower Tunguska (tributary of the Yenissei river). From the former place, two species of *Nöggerathia* were described by Prof. Göppert[3] as *Nögg. æqualis* and *N. distans*, and the formation from which they came was supposed to be Permian.

Quite recently, however, Mr. Schmalhausen has published a short paper on

[1] Münster: *loc. cit.*, Vol. VII, pl. II, fig. 2. Roemer, *loc. cit.*

[2] Owen: "Odontography," pl. XLII.

[3] Tchihatcheff: Voyage dans l'Altai orientale, 1845.

the Jurassic Floras of Russia,[1] where the Flora of the Kusnezk basin on the Altai is described as an undoubted Jurassic flora. Regarding the two mentioned species of *Nöggerathia*, Mr. Schmalhausen says, "The specimens described by Göppert as *Nögg. distans* and *N. æqualis* are apparently leaflets of a *Cycadeous* plant, related partly with forms of *Zamia*, partly with *Podozamites*. The name *Rhiptozamites* is proposed for the same." They are described as very numerous; with them occur *Phyllotheca*, *Asplenium whitbiense*, Bgt., sp. var. *tenue*, *Czekanowskia rigida*, Heer, *Pinus nordenskiöldi*, Heer, *Phönicopsis angustifolia*, Heer, *Samaropsis parvula*, Heer, and also *Gingko*, most of which occur in the Jura of Eastern Siberia and the Amur countries. Of *Cycadeaceæ*, the following were found: *Zamites inflexus*, Eichw., *Podozamites eichwaldi*, and a *Ctenophyllum*.

The genus *Rhiptozamites* is equally numerous on the Tunguska river.

A comparison of the Indian and Australian *Nöggerathiopsis* with the original drawings of the Altai *Nöggerathia* (Göpp. l. c.) shows that they are remarkably close to one another, and the genus *Rhiptozamites*, Schmalhausen, is a Jurassic representative of the genus *Nöggerathiopsis*, which in Australia begins in palæozoic beds, in India occurs in the Talchir-Karharbari and Damuda divisions of the Gondwána system[2] and in Siberia has a close (if not generically identical) representative in Jurassic rocks.

There are now especially three genera: *Phyllotheca*, Bgt., *Glossopteris*, Bgt., *Nöggerathiopsis*, Fstm. (and *Rhiptozamites*, Schmalh.), which begin in Australia in palæozoic rocks, and pass almost unchanged through the subsequent formations into Jurassic rocks in India and Siberia.

In my Flora of the Lower Gondwánas, I shall treat more closely of this genus, where I shall also refer to Count Saporta's recent papers on *Nöggerathia* and various plants included in this genus;[3] as also to some recent observations on the fructification of the Bohemian *Nöggerathia foliosa*, Stbg., which modify to a certain extent the classification given in Mr. Saporta's paper.[4]

NOTES ON FOSSIL PLANTS FROM KATTYWAR, SHEKH BUDIN, AND SIRGUJAH by O. FEISTMANTEL, *Palæontologist, Geological Survey of India.*

I. JURASSIC PLANTS FROM KATTYWAR.

In 1878, Mr. Fedden, while surveying a portion of the Kattywar peninsula, collected some fossil plants preserved in a friable sandy shale of purplish grey color. They are only very fragmentary, although the fragments are numerous enough; but as a certain interest attaches to them, I think it worth while to name them and discuss, as far as possible, their relations. The plants were found three-quarters of a mile north-west of Than, Northern Kattywar.

[1] Beiträge zur Jura Flora Russlands, 1879. Mélanges physiques et chimiques, Tome XI, tiré du Bull. de l'Acad. Imp. d. scienc. d-St. Petersburg, Vol. XXV.

[2] Permo-Triassic—if the Talchirs are considered as representing a portion of the Permian.

[3] Comptes Rendus des Séances de l'Acad. d. Sc., tome 86, 1878.

[4] While this short note was passing through the press, I received Mr. Schmalhausen's paper with figures, but too late for notice. I shall do so at an early opportunity.

FILICES.

Group of ALETHOPTERIS WHITBIENSIS, Schimp. (Feistm.) or ASPLENIUM WHITBIENSE, Heer.

There is one pinna of a fern which apparently belongs to this group of fossil plants, but it is one of the more slender forms, and is very closely related to the Jurassic *Asplenium argutulum*, Heer,[1] which also is to be included in the group of *Alethopteris whitbiensis*.

Alethopteris whitbiensis is known in India, especially from the Jabalpur and Umia groups; from the latter I have figured a specimen closely resembling that from Kattywar.

CYCADEACEÆ.

There is only one small fragment, which, I think, belongs to the genus *Ptilophyllum*; it indicates one of the narrow-leaved forms, to which belongs *Ptil.* var. *minimum*, Fstm. from Kach (Cutch); the same was also found in the Sripermatur group of the south-east coast of India.

CONIFERÆ.

Representatives of this Order are pretty numerous, especially leaved branchlets and seeds, although the former in no large specimens. The branchlets appear to me to belong to two species.

Palissya jabalpurensis, Fstm. The specimens are a little smaller than the original form from the Jabalpur group.

Taxites tenerrimus, Fstm. Several specimens are certainly to be referred to this form of the Jabalpur group.

The seeds are:

Araucarites cutchensis, Fstm. These are numerous, of various sizes. They are known from the Umia group, Jabalpur group, and Sripermatur group.

Besides these coniferous plants, there are numerous fragments of long narrow leaves, with a central vein in the better preserved specimens. My belief is, that they also are *coniferæ*, and in this case they most probably belong to the genus *Pinus*, resembling very much *Pinus nordenskiöldi*, Heer.[2]

A comparison of these fossil plants shows that they are related to the flora of the Jabalpur group by the presence of *Palissya jabalpurensis* and *Taxites tenerrimus*, Fstm; while *Araucarites cutchensis*, Fstm. is common to the flora of the Umia and Jabalpur groups. There is also a fern corresponding with a form from Katch and a fragmentary portion of a *Ptilophyllum*. These, with the *Araucarites cutchensis*, Fstm., would correlate this flora also with that of the Umia group in Kach, as was noticed in the Annual Report of the Geological Survey of India for 1878.

[1] Juraflora Ost-Sibiriens, 1876 (Flora fossilis arctica, Vol. IV, 1877), Taf. III, fig. 7.

[2] Beiträge zur fossilen Flora Spitzbergens, Tafel. IX, figs 1-6 (Flora fossilis arctica, Vol. IV 1877); Beiträge zur Juraflora Ost-Sibiriens und des Amurlandes, Taf. IV, fig. 8c (the same Volume), and Tafel. XXII, p. 4, a b., XXVII, 9a XXVIII, fig. 4.

Both these correlations appear (as far as the plant remains show) to be equally justified; and this is certainly of no small-interest, as this Kattywar flora thus forms a connecting link between those of the Jabalpur and the Umia groups, placing them, thus, homotaxially on the same horizon. This does not, of course, change anything of well established stratigraphical relations; and there is no objection that the same flora, which if considered from the Jabalpur group only has to be taken as middle Jurassic, should be found in the Umia group with and above upper Jurassic marine animals, and should still retain its middle Jurassic character, which view I maintain.

The case in Kach is, of course, easily solved: the formation is determined from the fauna, although this is associated with a flora of an older facies, but the question becomes more complicated where in the same beds there are found marine animals, of secondary and palæozoic types, as in the Salt-range, and in cases to be described by Mr. Griesbach from the Himalayan Trias.

2. Note on some plants from the Jurassic rocks at Shekh Budin (Upper Punjab).

Last year Mr. A. B. Wynne made a collection of fossils at Shekh Budín, comprising a few plant-remains, which, although very fragmentary, are of great importance, as being the first plants collected during the work of the Geological Survey in this northern portion of India. They are, however, not the only plants found in Upper Punjab. Dr. Waagen, in his note on the Attock slates,[1] mentions that there are in the collection of the Geological Society of London several specimens of plants from the Salt-range, although no recognisable specimens were yielded from that ground to careful search by the officers of the Survey.

The plant-fragments of Shekh Budín are preserved in a fine, slightly micaceous shale, of a light purplish-grey color, resembling certain plant-bearing shales of the Jurassic rocks in Kach, but more closely the shales of the Jabalpur group, near Jabalpur. The plants also, as far as determinable, recall those of the Jabalpur group.

The only fossils determinable with some certainty belong to the—

Cycadeaceæ.

Ptilophyllum(?) acutifolium, Mor.—There is a fragment of a leaf of a cycadeous plant, which belongs to the *Zamieæ* and which I refer to *Ptilophyllum*, for it appears from one of the leaflets that they are not free at the lower angle, but decurring; the upper angle, which is free, is rather a little more rounded than is usually the case in *Ptilophyllum;* but a specimen with very similar leaflets to those under discussion is figured as *Ptilophyllum acutifolium* in my Flora of the Jabalpur group,[2] Plate V, fig. 1.

Podozamites, sp.—There is another fragment of a single leaflet, traversed by longitudinal veins. This I refer to the genus *Podozamites*, and it appears to me

[1] Rec. Geol. Surv. of India, 1879, Vol. XII, Pt. 4, p. 184.

[2] Pal. Indica, Ser. XI, 2.

to represent the top portion, as the veins only approach each other without being dichotomous.

An identification of a fragment like this is always more or less uncertain, but in this case I think we can refer the fragment to *Podozamites lanceolatus* var. *eichwaldi*, Heer.[1]

This, although very unsatisfactory palæontological evidence, would so far show that these plant-beds of Shekh Budín have to be considered as representatives of the Gondwánas in the Upper Punjab in association with marine beds—a case like that in Kach, and on the south-east coast of India.

3. Lower Gondwana plants from the Auranga coal-field.

Mr. C. L. Griesbach, on his way to the Tatapáni and Rámkola coal-fields in Sirgujah, passed through the Auranga coal-field and collected a few fossils from a spot west of Murup, in beds mapped by Mr. Ball[2] as Barakars. Although I could only determine two species, I think them interesting enough for record.

Trizygia speciosa, Royle.—The occurrence of this fossil in this coal-field is of interest, as illustrating the geographical and stratigraphical distribution of the species. It was first made known from the Barakars of the Talchir coal-field, where it does not seem to be rare. Subsequently it was found to occur rather numerously in the Raniganj group of the Raniganj coal-field. This Raniganj form appears in general a little larger than that from the Barakars. Later on the same species was brought from the Barakars of the Bokháro coal-field by Mr. Hughes; and it is also known from the Bijori horizon (representing the Raniganj group) of the Satpura basin, in the upper Denwa valley; and now we know of it in the Auranga coal-field from the Barakar group. This species is thus almost equally numerous in the Barakar as in the Raniganj group.

There is no essential distinction between the Raniganj and Barakar forms, both show the characteristic "three paired" arrangement of the leaflets, the same distribution of the veins, etc. The only difference I could find is that already mentioned, between the forms from the Raniganj coal-field (Raniganj group) and Talchir coal-field (Barakar group); but the specimens from the Auranga coal-field (Barakar group) exhibit a size like that of the Raniganj form, so that even this character cannot be used as distinguishing the forms from these two groups, and both must be declared identical.

Glossopteris communis, Fstm.—This species is equally frequent through all the sub-divisions of the Lower Gondwanas.

4. Fossil plants from the Tatapani and Ramkola coal-fields (Sirgujah).

Last year (1878) a good collection of fossil plants was brought by Mr. C. L. Griesbach from the Tatapáni and Rámkola coal-fields. The fossils are from various localities and from various horizons. Mr. Griesbach, in his forthcoming report on the geology of these coal-fields, indicates the positions of the fossils in

[1] Juraflora Ost-Sibiriens und des Amurlandes, 1877, Vol. IV, p. 109, Pl. XXVI.

[2] V. Ball: Geology of the Auranga and Hutár coal-field (Palamow). Mem. Geol. Surv. of India, Vol. XV, Pt. 1.

each of his sections; it would, therefore, be unnecessary for me to discuss the fossils from each locality; it will be sufficient to speak of the fossils of each group collectively. In this area, the close palæontological relation of the several groups is also clearly illustrated, just as in the Satpura basin, especially, as it appears, between the Raniganj and Panchet groups; for there are fossils from several localities which, according to our present knowledge, correspond more with those of the Raniganj group, while the beds seem to be referable either to this group or to the Panchet group. I shall mention these localities further on.

The most interesting fact illustrated by the fossils brought by Mr. Griesbach is the satisfactory proof of the occurrence of the typical Raniganj group, as it occurs in the Raniganj field. This is shown especially by the numerous occurrence of *Schizoneura gondwanensis*, although, as we know, *Schizoneura* is not entirely wanting in the Barakar group, and is also not very rare in the Panchet group.

BARAKAR GROUP.

I come at once to speak of the fossils of this group, no fossils having been met with in the Talchirs, and also no equivalent of the Karharbári beds. As in the other coal-fields, there is here also no striking palæontological feature characterising the Barákar group, most of the fossils being common to all the sub-groups of the Damuda division, and its presence is with certainty demonstrated only stratigraphically; but a certain negative character can be used, *i. e.*, the absence (or rare occurrence in other cases) of *Schizoneura* (when compared with its numerous occurrence in the Raniganj group) and of certain forms of *Glossopteris*, which I shall mark presently as occurring in the Raniganj group, in which group the genus *Glossopteris* appears to be altogether more numerous.

I first enumerate the fossils from localities which apparently belong to the Barakar group (judged from the stratigraphical position); while at the end I shall mention several localities, about which, from a palæontological point of view, I can form no certain opinion.

1. *Equisetacea.*

Vertebraria indica, Royle.—The common form; found on the Sendur river, west of Mitgain; on the Ledho nalah near Karamdiha; between the Mahán river and the Tamor hill, near Majurdaki (southern field).

2. *Filices.*

Glossopteris communis, Fstm.—On the Sendur river, west of Mitgain; west of Chumra; on the Ledho nalah, near Karamdiha.

Glossopteris browniana, Bgt.—On the Sendur river, west of Mitgain.

Glossopteris (*damudica*, Fstm., MSS.)—This is a species which, like *Glossopteris communis*, occurs through the whole of the Damuda series, but is apparently most numerous in the Barakar group and in the iron shales. I have not described it yet, nor has it been figured, but I nevertheless introduce the name, as I shall have to refer to it again when speaking of the Raniganj fossils. From the Sendur river, west of Mitgain; between the Mahán river and the Tamor hill.

Glossopteris indica, Schimp.—Between Mahán river and Tamor hill (Majurdaki); north-west of Reonti.

3. *Cycadeaceæ* (?).

Nöggerathiopsis hislopi, Bunb., sp. (Fstm.)—This species, at first known from the Kámthi (Raniganj) group only, was later identified from the Barakar and Talchir-Karharbári groups also. Between the Mahán river and Tamor hill (Majurdaki); Suidud nalah, 1¼ mile north of Bheria.

The localities, the fossils of which do not indicate with certainty the Barakar group, are:

(*a*). West of Dhonda, from where I could determine:
Glossopteris indica, Schimp, and
Glossopteris communis, Fstm.

(*b*). Suknai nalah north of Sarsera: from here I determine:
Vertebraria indica, Royle.
Glossopteris communis, Fstm.

There is, however, no objection that these localities also should be mapped as Barakar, as is done on Mr. Griesbach's map.

RANIGANJ GROUP.

The occurrence of the Raniganj group in the typical form is, I think, well established in this field by the frequent occurrence of *Schizoneura gondwanensis*, Fstm., and of several species of *Glossopteris*, which hitherto are known from the Raniganj group only; I shall mention them presently; one is already a described form, the others are new.

1. *Equisetaceæ*.

Vertebraria indica, Royle, the more branched form, as known from the Kámthi (Raniganj) group; between the Mahán river and the Tamor hill; nalah between Gouri and Ghui; in the Morne river, north of Parasdiha.

Schizoneura gondwanensis, Fstm.—Several pieces of shale are filled with specimens of this species, just as is the case in the Raniganj field, and also the shale agrees with that of the Raniganj field. The specimens are in layers, one over the other, preserved as leaved stalks of various sizes and as single leaves. It is additional evidence to the wide geographical distribution and frequent occurrence of this species in the Damuda series, especially in the Raniganj group.

We know this species at present from—

(*a*), the Raniganj group of the Raniganj coal-field, where it is very numerous; from the Jherria coal-field; from the Hingir coal-field; from the Tatapáni coal-field, where it appears to be also numerous; and from the Satpura basin, where it is known from two localities (in the Bijori horizon);

(*b*), from the Panchet group, in the Raniganj field, where it occurs pretty numerously.

(*c*), from the Barakar group on Lumki hill, in the Karharbári coal-field;

(*d*), from the Talchir-Karharbári beds in the Mohpáni coal-field, and (?) from the Talchir shales of the Deogarh field.[1]

In the Tatapáni coal-field it occurs along the nalah at Budatand and near Lanjit.[2]

FILICES.

Glossopteris angustifolia, Bgt.; this narrow-leaved form is especially known from the Raniganj group.

Banki Nalah, between Chumra and Gidhi; between Mahán river and Tamor hill; Morne river, north of Parasdiha; Budatand nalah, near Budatand, south of Nowadih; in the Ledho nalah.

Glossopteris retifera, Fstm.—This also is a Raniganj form. Banki nalah, between Chumra and Gidhi.

Glossopt. communis, Fstm.—Banki nalah, between Chumra and Gidhi; east of Ghui; south of Nowadih; in the Ledho nalah.

Glossopt. indica, Schimp., between Chumra and Gidhi.

Glossopteris, sp., a peculiarly oval leaf, which, I think, will prove a new species. One specimen of the same kind is known from the Raniganj group of the Raniganj field, and also the rock agrees completely. The net venation is much like that of *Glossopt. communis*, but still finer and narrower, and the midrib diminishes suddenly towards the apex. I shall describe this form in the next fasciculus of the Lower Gondwána Flora. North of Meguli (Moholi on map).

Glossopt. damudica, Fstm. (MS.)—This species is already mentioned above. Morne river, north of Parasdiha.

Glossopteris, sp.—Another species was found in the Tatapáni coal-field, identical with one from the Raniganj field (Raniganj group), not yet described; it is a narrow leaf, with a large net venation, the veins passing out from the midrib at an acute angle. South of Nowadih.

From these fossils, the Raniganj group is certainly quite well established.

There are a few other localities, which palæontologically might be still placed in the Raniganj group, while stratigraphically they seem to be on the Panchet horizon.

a. Nalah west of Narola—
Glossopteris, sp.

b. In the Ledho nalah—
Glossopteris angustifolia, Bgt.
Glossopt. communis, Fstm.
Glossopt. indica, Schimp.

c. Near Karamdiha—
Glossopteris communis, Fstm.

[1] The specimens appear at least to be *Schizoneura*.

[2] This portion of the Lower Gondwánas near Lanjit is colored as Barakars, the strata being much broken up by dykes, etc., so that no distinction of beds could be made out. The frequent occurrence of *Schizoneura gondwanensis*, Fstm., at this place would refer that portion to the Raniganj group.

These localities thus yield an unusually large number of *Glossopteris*, while in the Panchet rocks, although its occurrence is undoubtedly established, it is only known to occur rarely, and fragmentary. At these localities, however, it occurs in the same manner as in the Raniganj group, and we have either to acknowledge the closest connection of the Panchet and Raniganj groups (which in this field also seems to be shown stratigraphically), or to account for the uninterrupted passage of the Raniganj flora into the Panchet group, in which case the close relation of both is again shown. It is, of course, possible that the observations upon which these suggestions are based might be modified by a revision of the survey, but taking the lines as laid down by Mr. Griesbach, we may now say that three-fifths of the species in the Panchet group are those of the Raniganj group.

This mutual relation of the Raniganj and Panchet groups in this field, is so far interesting and important, as at the two last-named localities there occurs a plant which appears to be a *Thinnfeldia*. I shall describe it more closely in my Flora of the Lower Gondwánas.

MAHADEVAS.

In succession to the Raniganj-Panchet rocks the Mahadevas are highly developed, as in the Satpura basin; and they have proved equally poor in fossils. Mr. Griesbach discovered only at one locality some fragments of plants, which do not admit of specific determination: one is an *Alethopteris*; the other is doubtful, even as to the genus; it is either a *Tæniopteris* or *Glossopteris*.

The Mahadevas in this area seem to be to the Panchets in the same close relation as in the Satpura basin, where the whole Gondwána system is developed, from the Talchirs (bottom) to the Jabalpur group (top), and these basins where the succession of the several groups is also continuous, are, therefore, of the same interest for the correlation of the various groups.

ON VOLCANIC FOCI OF ERUPTION IN THE KONKAN, *by* GEORGE T. CLARK, ESQ.[1]

I chanced yesterday, in the library of the Athenæum Club, to meet with the two volumes upon the geology of India to which are prefixed your name and that of Mr. Blanford, and in vol. 1, page 327, I lighted upon some remarks very complimentary indeed to myself, but which do not, I think, refer quite correctly to what I advanced, now thirty years ago, on the geology of the western side of the Indian peninsula, in the neighbourhood of Bombay. I therefore address myself to you by letter, and I must ask you to excuse the length into which I may probably be betrayed.

At the time that I reached Bombay in 1844, nothing was known about the origin of the trap of Western India, and I found from Mr. Orlebar, and, I think,

[1] Mr. Clark's observations and views upon the trappean rocks of Western India are much more clearly brought out in the letter (dated 25th July 1879) published above, than in his original papers in the Quarterly Journal Geol. Soc., London, Vol. III., p. 221, (1847) and Vol. XXV, p. 164 (1869), from which the notice in the Manual was taken. The obscurity upon the important question of denudation is now quite cleared up.—H. B. MEDLICOTT.

from Mr. Malcolmson, both very competent geologists, that even Bombay and Salsette had not been geologically examined, and that little was known of their details and still less of those of the Konkan on the opposite side of the harbour. Feeling much interest in the subject, I determined, while visiting the Island and the main land for other purposes, to pay what attention I could to the geology. I began with Bombay, and spent some time in laying down the dip and direction of its rocks, which I found to be mostly igneous, traps and greenstones, with occasional intervening beds, probably of sedimentary origin, all dipping more or less westward at a high inclination. While thus engaged I was fortunate enough to fall in with a bed, newly uncovered, containing very perfect remains of batrachians, which lay immediately beneath a sheet of basalt capping the western side of the Island of Bombay, and which was evidently its latest formation. I sent home to the late Dean Buckland some specimens of the fossils, which were figured in the Journal of the Geological Society (Vol. III, p. 224), and thus the geological date of the basalt was established. I found the same dip and bearing to prevail in Salsette.

On reaching the Konkan, and pausing near Kalian, I was much struck with the difference between the outline of the eastern and western eminences. The hills of Salsette were sharp-topped and steep, all their lines more or less inclined and covered to the top with vegetation, whereas the hills, or rather mountains, of the Konkan, were flat-topped, their leading lines horizontal or nearly so, their sides terraced, the terraces divided by cliffs, and the tops, at least, bare of vegetation. It seemed as though in the one case the beds, being tilted, had allowed the rain to penetrate and produced disintegration, while in the other, the beds being flat, resisted penetration and its consequences. It was also clear that the eastern mountains, as Towlee, Bhow-mulling, and Matheran, were outliers from the great mass of the Western Ghauts, strictly conformable to them in their structure, and that the dip of their beds, so slight as to appear locally horizontal, was really towards the east, and with a remarkably uniform inclination.

This contrast, obvious at the first glance, led me to suppose that the origin of the traps must be sought for either in the trough of Bombay harbour or in the adjacent margin of the Konkan, or wherever the beds dipped from a centre or central line. It was further evident, with so complete a correspondence between the beds of the outliers and the main range, that the whole must at one time have been continuous, and that a vast mass of intervening matter must have been excavated and removed.

Following out these ideas, I proceeded to examine the floor of the Konkan, at first along its western edge towards Panwell, and then more minutely along a line which pointed westwards from Kalian towards the great bay of the Malsege Ghaut, and which presented some very remarkable appearances.

The rock beds, so far as I observed, at or near the level of the floor of the Konkan, which was not much above that of the sea, were all of a uniform variety of trap, and all amygdaloidal, the vesicles being mostly filled with zeolite. Usually the lower part of each bed was more or less solid, and the upper part vesicular. The vesicles were of all sizes, up to a length of 12 or 13 inches and a diameter of 3 or 4, and they were frequently elongated, as though the trap,

while viscid and full of air bubbles, had flowed in the direction of their longer axis. Occasionally also the vesicles were bent and twisted, as though the trap had flowed over a hard edge, as water over a weir; particulars which seemed to afford a clue to the direction, and in some degree to the circumstances, of the flow. Following upon these indications, I found that I reached a number of hillocks or cones, hollow in the centre, and often with a gap in one side, and within and about these the trap often lay in small streamlets, crossing over or overlapping one another, but all evidently derived from a common source or centre. Frequently these streams had flowed for some distance in parallel lines impinging upon each other, not uniting, so as to leave a V-shaped trough between them, which again was filled up with other streamlets. All these had assumed various shapes according as they had flowed in a trough or over a flat surface, or over an obstacle, or had dropped over some accidental step or fissure in the subjacent rock.

These singular, crater-like, hillocks lay very thick together along the course of the Bervee river above Kalian, and upon that of the upper Kaloo near Bhalook and Kinnowlee. Near the ancient temple of Oombernaut are several, some with a central hollow a quarter of a mile across and sides from 200 to 300 feet high. The interior slope is much steeper than the exterior, and the floor is usually very hard and undulating, as though it had been in a state of ebullition.

Besides those hillocks are also a number of flattened domes very distinct, though of no great height, like huge bubbles of very hard rock, and seen, where the surface is broken, to be composed of layers like the coats of an onion.

These are especially frequent in the upper Kaloo approaching the Malsege. I observed also in the bed of this river, dry or nearly so when I saw it, that in many places it was not excavated as by water, but formed by the parallel junction of two lava streams, the stream filling up which had been dissected out, not eroded, so that the surfaces remained smooth and sometimes almost glazed.

All these appearances led me to believe that I had lighted on a number of foci of volanic or plutonic action, placed along certain lines, and that these were the vents—perhaps sources would have been a safer word—whence the traps of the district, and of the adjacent islands on the one hand and of the Ghauts and Deccan on the other, were derived. I came also to the conclusion, perhaps upon the examination of too limited an area, that the general line of the sources lay nearly north and south down the edge of the Konkan, pointing towards the islands of Heneri and Keneri, and that the line towards the Malsege was a sort of spur or lateral axis, accounting probably for the existence of that very remarkable bay or indentation into the main line of the Syhadree range.

The contrast was remarkable between the irregularity of the streamlets of lava in the plain and near the sources above described, and the excessive regularity of the beds at higher elevation, and at a distance from those points.

This indeed was what might have been expected; a regular and uniform dip being more likely to be arrived at by a lava sheet at a certain distance from its source.

But the above are not the only remarkable features connected with these sources. There are found generally, in the Konkan, large numbers of basaltic dykes, more or less vertical, and usually running in lines straight or nearly so. These are of various breadths, up to 40 feet or even more, and they occur most frequently near the sources or craters described above. Thus there are numbers of them about the Bervee between Kalian and Budlapoor, and they are especially thick between Moorbar and Kinnowlee, and at the head of the Malsege bay, under Sindloo and Hurreechunder. Not only are they found in the floor of the Konkan, but they are seen to cleave the highest eminences of the ghauts, and they extend for some miles in to the Deccan, showing that they were poured out and injected after the great mass of the trap was laid down. It is remarkable also, that though so broad and extended so far as I saw, they are rarely, if ever, connected with any displacement of the intersected beds, or anything like a fault. It is remarkable also that the basalt which in Bombay is spread out as a sheet over the highest of the trap and greenstone beds, also caps the elevations of the ghauts, as may be seen at Khardalla, Beema-Shunker, and other places, though whether these horizontal sheets were caused by the overflow of the dykes, or whether, as is more probable, their material overflowed the craters in the usual way after the trap period had ceased, I could not ascertain. It is, however, evident from the mechanical position of the basalt whether in dykes or sheets, as well as from its relation to the batrachian fossils, that it was thrown up after the trap; and probably both dykes and sheets, though not simultaneous, belong to the same geological period.

The basalt dykes deserve close attention. They are generally vertical, and very rarely magnetic. Also they are almost always composed of small prisms, the axis being at right angles to the course and faces of the dyke. Also they are commonly fringed at each face, the fringe or 'selband' being broken up by vertical planes, parallel to the face of the dyke. The dyke beneath the fort at Kalian is columnar. The basalt is usually homogeneous, though now and then its surfaces are pitted as though small deposits of minerals had been washed out. There is no cohesion between the prisms, so that the dyke is often a mere trough, the matter being removed. Near the Wanaghaut where a large dyke cleaves the nearly precipitous face, the basalt is so far removed that the dyke is represented by a hollow chasm, and forms a steep stair-case, up which is a path for foot passengers.

Although there is no vertical displacement connected with these dykes, the heat of the basalt has hardened and rendered tough the contiguous trap. The effect of this is curious. In the plain near Moorbar the country is intersected by a net work of steep and narrow banks from 100 to 200 feet high, somewhat resembling the junction of a number of lines of railway in embankment. The axis of each of these banks is a dyke, the toughness imparted by which has enabled the banks to resist erosion, while the place of the dyke is marked by a trough a few feet deep, out of which the basaltic prisms, being loose, have been removed.

Looking back to the immediate causes of the very peculiar configuration of the

country between the ghauts and the sea, it occurred to me that what I there saw was not unlike what would be seen if the island of Sicily were to be submerged, and Etna be acted upon by water currents. The central part, being shattered, would easily be removed down to the nuclei of the several craters, and the flanks of the mountain being much less shaken would remain and present more or less of a scarp at their innermost and highest edge, and their surface, like that of the Deccan near the ghauts, would be hollowed into ordinary valleys of excavation. If for a single central point one or more lines of action were substituted, the effect would be pretty much what is now seen in the Konkan. Possibly the same effect would be produced by atmospheric action, only in such a case an enormous period of time would be necessary.

Then, as to the contrast between the beds forming the ghauts and those in Bombay and Salsette, the former at a certain distance from the line of action fall with a uniform and gentle slope, whereas the western beds fall at an opposite and much greater dip, and are more or less broken. This I supposed to be due to the previous configuration of the ground. I thought the base of Konkan and the Deccan to be a mass of metamorphic rock, over which the trap flowed at an easy slope, while to the west the same trap flowed into the deep sea. I understand, however, that late researches are opposed to this latter notion, and that there is reason to think that the greater dip of the western bed is due to a subsequent subsidence. This, of course, does not materially affect the question of the common sources of these rocks.

I remark also that the present, and I dare say the correct, opinion is that these traps are subaerial and volcanic. I supposed them to be submarine and plutonic, because they seemed to me to have been erupted under immense pressure. This again does not materially affect the leading inferences derived from my observations.

In concluding this long and, I fear, tedious letter, I may be allowed to remark that it is many years since I have paid attention to this or any other geological subject, and that neither formerly nor now have I any pretensions to be called a geologist. I brought home with me a vast collection of samples from every dyke I met with, each labelled with the direction, breadth and leading features of the dyke. I sent these in 1848 or 1849 to the Geological Society, where they were seen by Mr. Horner and the then Secretary Mr. Lonsdale. These gentlemen, however, did not think them worth the space they occupied, and as they declined them, I caused them to be thrown away, nor did I again trouble myself on the subject, until some years afterwards I saw to my surprise my name mentioned in a paper by Mr. Wynne as one of the pioneers in the geology of Bombay.

I am not sorry even now to find or make an opportunity of bringing under your notice as the head of the Indian Survey a sketch of what I did in the field so many years ago. You are necessarily aware of the difficulties attendant upon field work in the Konkan, and will therefore extend to my labours that charity that I suspect they much require.

I add a tracing of a map showing a few of the centres of action, and most of the dykes observed in the Malsege or towards Kalian.

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Donors.

Two spinel-rubies, with a specimen of the matrix: from the Jagdalak mine.

MAJOR STEWART,
Corps of Guides.

Verde antique serpentine, from Shigar, Ladák: it is locally called *Yesham* (jade).

MAJOR BIDDULPH.

ADDITIONS TO THE LIBRARY.

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Titles of Books. *Donors.*

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BALL, V.—On Stilbite from Veins in Metamorphic (Gneiss) Rocks in Western Bengal (1878), 8vo pamphlet, Dublin.

V. BALL, ESQ.

BARRANDE, JOACHIM.—Réapparition du Genre Arêthusina Barr. et Faune Silurienne des Environs de Hof en Bavière (1868), 8vo, Prague.

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G. NEVILL, ESQ.

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BRONN, PROF.—Sur les Lois de la Distribution des Corps Organisés Fossiles dans les Différents Terrains Sédimentaires suivant l'Ordre de leur Superposition (1861), 4to, Paris.

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MINISTERIAL DEPARTMENT, CAPE OF GOOD HOPE.

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FOUQUÉ, F.—Santorin et ses Éruptions (1879), 4to, Paris.

GILBERT, G. R.—Report on the Geology of the Henry Mountains (1877), 4to, Washington.

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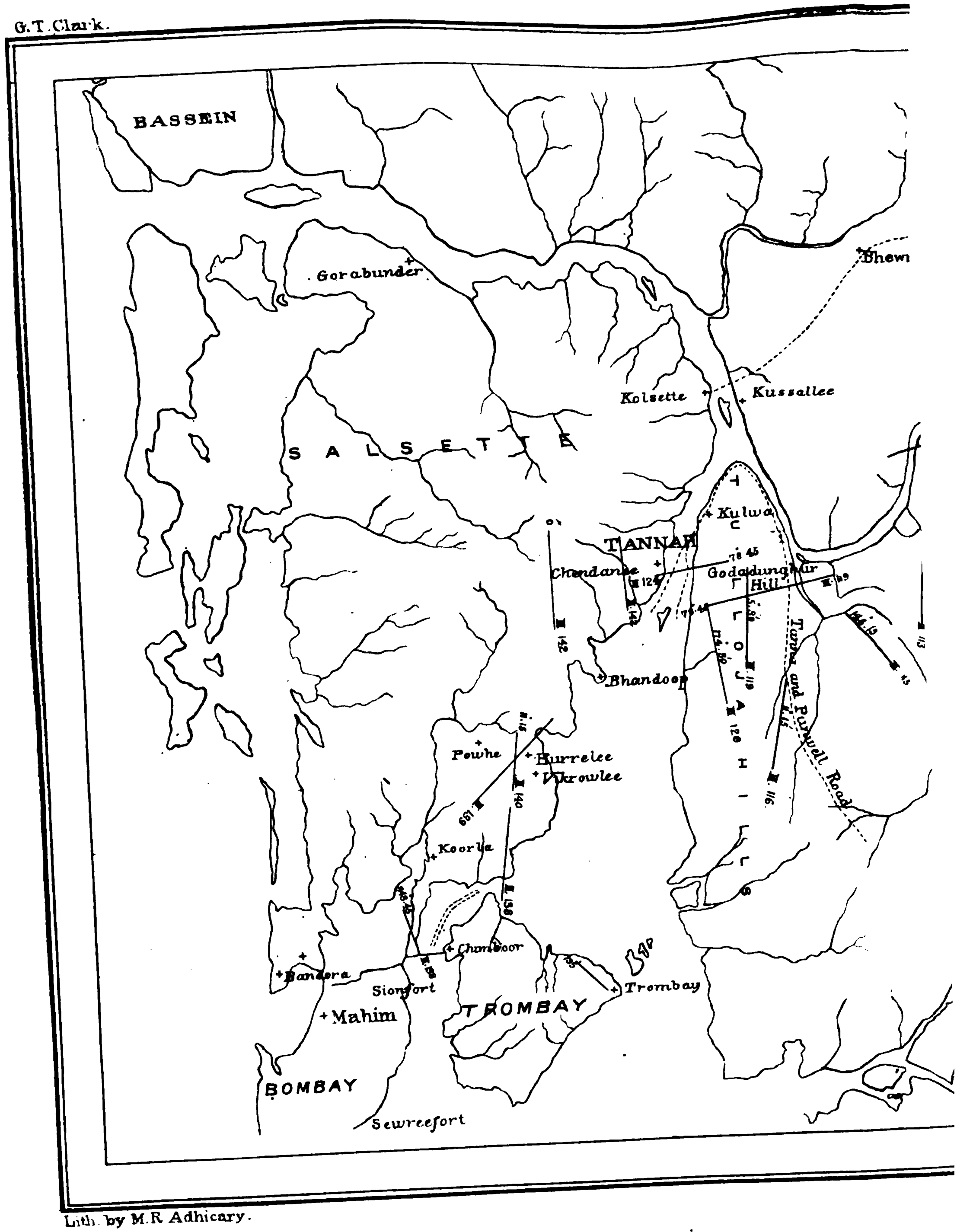
G.T. Clark.



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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1880. [May.

GEOLOGICAL NOTES *by* C. L. GRIESBACH, F.G.S., *Geological Survey of India.*

1. *The metamorphic rocks of the Himalayas.*—It is not my intention to describe here in detail the rocks composing the Himalayas; for this I may refer the reader to the pages of the Manual and the Memoirs. I will only state that I could not see any material difference either in lithology or any other character between the metamorphics of the plains of India and those of the hills. Here as there we have a great deal of gneissic rocks of a porphyritic structure, traversed by many veins of granites of various character, and in that, I may here mention, these rocks reminded me forcibly of the granitic gneiss of the Cape, with its large felspar twin-crystals, to which Hochstetter has long ago drawn attention. Here as there we have folds of metamorphic schists of every lithological variety, traversed by hornblendic dykes, probably old trap outbursts. And both in the Peninsula and the Himalayan chain, the average strike of the metamorphic rocks is somewhere from east to west, and in that also these rocks correspond with the metamorphics of South and Eastern Africa.

When traversing the Southern Himalayas from south to north, two gneissic areas are met with, parallel to each other, and extending more or less along the whole known part of the mountain chain. The first line is in the lower mountains south of the main chain, and in the Kumaun section the Almora hill is a point in that line. Further north is the main gneissic area of the great southern or Indian snowy range, with Nandadevi, Trisul, Mana, and other giants rising far above 24,000 feet. Between and skirting these gneissic lines, a series of metamorphic schists form most of the intermediate ground. In the Kumaun sections, they are found to dip north inside the first range (Naini Tal, etc.), and to pass with the Almora gneiss below the Bageswar limestones; in this formation the dip is rolling, once south, then north again, and finally it appears to pass under the second and great central gneiss area, but in reality the strata form with the latter a great fold, the upper part of which has been removed by denudation. On the other side of the gneissic area the schists re-appear again, reclining on the gneiss, and finally dipping below the old slate formation, which I shall presently prove to be not younger than Cambrian.

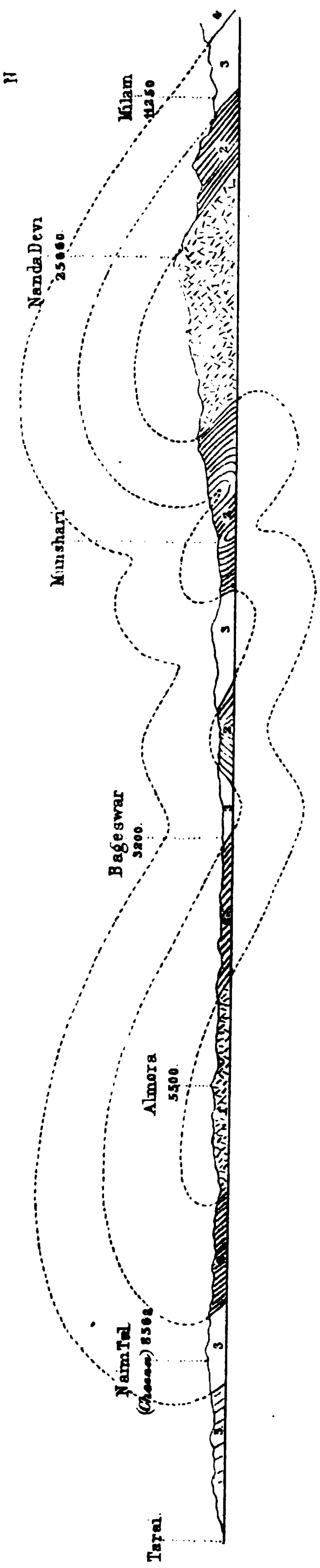


Fig. 1.—Section of the Himalayas between the Tarai and Milam, in natural scale.
1, Gneiss with granite veins. 2, Schists. 3, Cambrian slates and limestones. 4, Silurians. 5, Tertiary series of the Bhábar.

The features may roughly be sketched as shown in the annexed section, in which I have, of course, omitted all the numerous minor folds and a few faults and dislocations which must of necessity occur where such enormous tension existed.

2. *Pre-Silurian rocks of the Himalayas.*—Nearly all sections through the Himalayas reveal on the northern slope and *below* the fossiliferous Silurian series a formation which has often been noticed and always been described as the "Slate series." The lowest member of it is probably a greenish silky and semi-metamorphic slate, seen near Milam to pass into the schists below. But higher up it passes soon into a purple or dark blue quartzite in thick beds associated with beds of a peculiar jasper-like conglomerate, which in some sections forms the lowest bed near the contact with the metamorphics. Not a single trace of fossils has been found in this group, which is very much contorted. It is now crumpled up into a narrow strip, so that its thickness cannot even be guessed at.

Higher beds, consisting of silky greenish slates, quartzites, and lastly, of a dense red quartz-slate, seem at a few places to rest unconformably on the lower group, and everywhere dip below the fossiliferous *Lower Silurian* formation.

A few indistinct traces of Bivalves, and Pleurotomaria? Bellerophon? were found in it. There is very little doubt as to the propriety of classing these last rocks with the *Cambrian* series of elsewhere, on the grounds of their relation to the overlying strata, which by their fossil contents are abundantly proved to belong to the *Lower Silurian system.* The lower group of quartzites and conglomerates may then be termed *Lower Cambrians;* and the whole rests more or

less conformably on the underlying metamorphic series, and shares with the latter in the general folding and disturbance of the strata.

In one or more of the folds of metamorphic rocks shown in the section, fig. 1, I found inclosed and folded into a narrow strip a mass of limestones, calcareous conglomerates and shales, here and there silicious, which at once reminded me of the Cambrians of the northern slope of the Himalayas. There the conglomerates consisted entirely of quartzites, the same as the cementing matrix, and formed with the latter a very hard jasper-like rock. Here the conglomerates are a hard grey, silicious limestone, pebbles as well as matrix. I believe that the Bageswar limestone really represents a limestone facies of the slate series or Cambrian; and in connection with the folding of the metamorphic series I consider them part of the same marine development of the Cambrians, now severed from the strip north of the central fold by the erosion of the upper arch of the anticlinal.

As indicated in the sketch section, fig. 1, I include the Naini Tal (Cheena) limestone for the present in that old Cambrian formation. Though the relations of this rock to the neighbouring tertiaries and basaltic traps is not quite clear, it seems best for the present to class them with the Bageswar rocks, with which they have much in common. The Naini Tal beds seem to dip below the metamorphics, but in reality rest above them and merely conform with them in a curve, which, as nearly all the larger ones in this section, have lost the upper arch by denudation, as shown in the above-mentioned section. It is needless to state here that the Naini Tal limestone has been compared with the Krol limestone of Simla.

3. *The Pre-Silurian rocks of the Peninsula.*—In Central and Southern India there is found a formation, covering the metamorphics in patches, and in some places overlaid by the Vindhian sandstones. Various are the strata occupying this position between these two rock groups, though mostly silicious, here and there calcareous, with beds of conglomerates, and as yet believed to be wholly unfossiliferous. Last year whilst traversing the Vindhian range on the Sone river, I observed a series of rocks, jasper-like conglomerates, quartzites and grey, almost crystalline limestones underlying the lower Vindhian sandstone near Agori Khas, which afterwards I could not help but compare with the similar rocks of the Himalayas. Here as there they rest directly on the metamorphic rocks.

4. *The Palæozoic rocks of the Himalayas; Silurian to Carboniferous.*—Directly resting on the Cambrian slate series I found a group of rocks as follows :—

Hanging: Lower Trias.

(About) 350′	white quartzite with	Carboniferous ...	... 4
350′	red crinoid limestone		
666′	coral limestone ...	Devonian? ...	... 3
1,129′	quartzite and slates ...	Upper Silurian ...	... 2
208′	coral limestone ...	Lower Silurian (Caradoc)	... 1
6,573′			

Lying: Upper Cambrian.

I will not now enter into the description of this series, all the beds have proved rich in fossil contents, excepting group 3, which has only yielded a few casts of Orthoceras and a few Corals, which may be either Devonian or Carboniferous. Most of the fossils have already been described by General Strachey, and Messrs. Salter and Blanford. It is an uninterrupted series of beds, passing one into the other almost imperceptibly, but bearing unmistakable fossil evidence, the lowest bed of which, above the Cambrian slates, contains many of the English Caradoc forms, and the uppermost member of which group of rocks (the white quartzite) contains true Carboniferous brachiopods.

5. *Break between Carboniferous and Trias.*—The close of the Carboniferous series marks a great change in the Himalayan area. The next succeeding series of rocks resting on the Carboniferous is the Trias, ushered in by its lowermost member, the *Alpine Werfen beds,* with *all* its characteristic fossils. In some of the sections the contact of the two groups is apparently perfectly conformable, but the absence of the white quartzite in some sections, when the dark bituminous and micaceous Trias-base rests directly on the Red Crinoid limestone, besides the total absence of the Permian group, clearly points to a change of conditions, which must have taken place, at least here, after the close of the Carboniferous epoch. The explanation of this must be sought elsewhere.

6. *The Palæozoic rocks of South Africa.*—Some time ago I had the good fortune to be able to study three great cross-sections through South Africa and part of a fourth, namely—

(1) From Table Bay to the Great Karoo;
(2) From Algoa Bay inland;
(3) From Port Natal to the Drakensberg; and
(4) About 200 miles up the Zambezi on the east coast; but this latter is made very complete by the help of the observations of the late Mr. R. Thornton, the geologist of the first Livingstone expedition, whose extensive journals were placed in my hands by the Royal Geographical Society.

But one of the best sections, and also the earliest described, is the first,—between the Table Bay and the Great Karoo, a distance of about 140 miles. As this one illustrates all the features for comparison with our Indian formations, I will select it for the purpose.

The lowest rock seen is a gneissic and porphyritic granite, which forms the base of the Cape Table-mountain, of the Devils-peak and Lions-rump. It is seen in several places along the section cropping up with other metamorphic rocks beneath a slate formation, containing fossils. This slate formation probably represents all the lower palæozoic rocks. The great mass of it appears to be of *Devonian* age, proved so by an abundant fossil yield. It is very probable that also the lower palæozoic formations are there represented, as Hochstetter has already hinted at,[1] and recent finds of fossils make this very probable.[2] The whole is very much contorted and rolled up, evidently by a side pressure coming

[1] Dr. F. von Hochstetter: Reise der Oesterr. Fregatte Novara: Geol. Theil., p. 32.
[2] H. Woodward: Quar. Jour. Geol. Surv., 1872, p. 31.

from the south,—the general strike being about east to west or nearly so. Devonian beds with almost the same fossil contents are found in the Falkland Islands, South America.

Quite unconformable on it lie the so-called Table-mountain sandstones. I need scarcely say that, as the name implies, the stratification is almost horizontal, sometimes quite so, thus forming a marked physical feature in the landscape. They are made up of red and brown gritty sandstones, of hard quartzites and partings of silicious shales.

When I crossed the Vindhians last year, I was at once, and forcibly, reminded of the South African tablelands, not only by the similar scarped outlines, but also by the similarity of lithological character.

A few thin seams of coal have been found in the Table-mountain sandstone, and a few badly preserved traces of fossil plants, probably of Lepidodendron, pointing to a Carboniferous age and to fresh-water conditions. As Hochstetter has already pointed out long ago, the Table-mountain sandstone is enclosed between the Devonian formation on one side and the lower Karoo beds on the other; the latter are most likely of Triassic or Permian age, so therefore the age of the Table-mountain sandstone becomes, as a matter of course, Carboniferous.

The close of the Carboniferous epoch marks a great change of conditions here. A steady pressure from the south, which before had already lifted the Devonian deposits above the level of the sea before the deposition of the sandstones, resulted in crushing and faulting of parts of the horizontal beds of the Carboniferous, and a further rise of a fringing southern belt of the Table-mountain sandstone, with a corresponding depression northwards, in which the first deposits of the Karoo series could be laid.

We see therefore that it is with the *close of the Carboniferous that changes of conditions begin, and an entirely new series of forms appear of a decidedly mesozoic type. There is a break*, into which nothing will fit, but perhaps a widely extended boulder bed at the base of the succeeding Karoo beds, and as yet found devoid of organic remains.

7. *The Indian Peninsula during the palæozoic epoch.*—As noticed above, a series of rocks of a semi-metamorphic character occupies in some parts of Central and Southern India the position between the metamorphics on one side and the Vindhian sandstone on the other. These rocks have received many names and are described at length in our Memoirs. Since all are older than the Vindhians, and in some respects analogous with the marine Cambrian deposits of the Himalayas, I may class them together as representing the Cambrian series. With the Cambrians of the Central Himalayas they have this structural character in common, that they share with the underlying metamorphics in all disturbances which have affected the latter both in the hills and in the Peninsula, and that the succeeding formation shows, in places at least, an unconformity. As I have shown above, there is an uninterrupted series of marine palæozoic rocks to be found on the north slope of our Himalayas; not a single member of the marine series is met with south of the central range, and it is fair to assume that the present central range marked the palæozoic boundary between land and ocean, or very nearly so. If my assumption is correct that the pre-Vindhian rocks are identical

with the Cambrians of the Himalayan area, then it is also certain that the change of physical conditions took place near the close of that epoch, and this is proven by the unconformity which marks the junction with the overlying rocks, in the hills the Silurians. Now, assuming that this break after the pre-Vindhian epoch corresponds with the one which occurs after the deposition of the Cambrians in the hills, we further perceive that on one side (Himalayas) we have a great series of marine palæozoic rocks, whereas on the other side (the Peninsula) only a mass of sandstones, quartzites, and shales is found next in succession. From henceforth the physical conditions of the peninsula are those of *terra firma*, and it is beyond doubt that some of the sandstones may represent one or more members of the palæozoic series. It has before been assumed that the Vindhians may be Silurian, perhaps even pre-Silurian, but I argue that the Vindhian sandstones, &c., represent the *whole* of the palæozoic rocks up to the close of the Carboniferous, and that there was not a long continued break between the deposition of the last Vindhians and the lowest Gondwana rocks. Ascending the scale of palæozoic rocks in the hills we find an unbroken series until we reach the close of the Carboniferous rocks, where we find *a break*—Triassic rocks of European type resting directly on Carboniferous. Some disturbances must have taken place to produce this break, changes of physical conditions which must have affected the Indian Peninsula. Now, if we search for the signs of these changes south of the central range, we notice the first unconformity, the first break between the Vindhians and the Talchirs. There is therefore good evidence that the former are simply the freshwater facies of the whole of the palæozoic series and that the Upper Vindhians represent the Carboniferous formation. And indeed this is likely enough if we compare this group with the similar Table-mountain sandstone of the Cape; these two groups not only resemble each other in petrological characters, but occupy relatively the same geological position.

8. *The mesozoic formations in the Himalayas.*—On the Carboniferous in the Kumaun sections, and on older rocks elsewhere probably, we find the mesozoic series ushered in by beds corresponding to the Bunter-Sandstein of Europe, or more correctly to the *Werfen* beds of the Alps. I was able to distinguish the following groups of the Trias and Rhætic[1] :—

Rhætic	*Avicula contorta* beds		2,213′
	Lithodendron-limestone (*Megalodon triqueter*) with several partings of fossiliferous beds, probable representatives of the lower Kössen beds of the Alps		
	Dolomites with partings of Lithodendron-limestone		
Trias ...	Brown limestones with greenish shales	782′	1,662′
	Greenish shales	160′	
	Black limestones, with splintery shales	483′	
	Grey limestones	50′	
	Limestone, earthy	8′	
	Campiler, Seisser (Werfen beds)	184′	

[1] For a more detailed description and correlation of the Triassic and Rhætic series, I refer to the companion paper in this number of the Records "*Palæontological notes on the lower Trias of the Himalayas.*"

The topmost bed of the Rhætic passes into a thin bed (which is wanting in some sections) containing already Liassic forms, but after that a break occurs. Not a single member of the lower Oolite is found, the only representative of the Oolite (the well-known Spiti shales) contains forms of the upper-middle Oolite. The upper Jurassic beds are quite unfossiliferous dark shales. On them rest cretaceous greenish shales (olive shales of the Punjab ?) and quartz sandstones capped by a white limestone with many cretaceous fossils (Stoliczka's Chikkim limestone).

9. *The mesozoic groups of the Peninsula.*—As already explained in the above notes, we meet with the first great break of deposits of the Peninsula between the upper Vindhians and the lowest Gondwána rocks, a break which I have tried to demonstrate must represent the break which is found between the Carboniferous and the Trias groups of the Himalayan area, and which therefore falls into the Permian epoch, an epoch which, both in Europe and North-Western Asia, represents a passage between the Palæozoic and Mesozoic types of life.

We know that great changes of land and water took place in the Australian region during Carboniferous times, and partly continued during the following periods. Into that epoch fall the deposits of the lower group of beds containing many plants of carboniferous aspect, described by Dr. O. Feistmantel[1] and associated with forms again met with in the shales and silty beds of the Talchirs and Karharbari group, figured and described by the same author. We must assume a disturbance of some continuation and magnitude to explain both the unconformity of the Talchirs on Vindhian and the Trias on Carboniferous series in India; accompanied as it is by an influx of forms belonging to the upper Carboniferous of Australia, it is only fair to assume that a pressure was exerted towards India from the south-east, causing a successive "landwave" to transmit eastern forms of terrestrial life, to travel west and perhaps northward—to India and China.

I believe the direction of this great landwave to have been nearly at right angles with the line of strike of the older north-east wave, which caused the distribution of land and water to change during palæozoic times, traces of which are found in the post-Cambrian both in the Himalayas and the Peninsula.

We see the existence of these two waves clearly exemplified in the present shape of the Peninsula not less than in the long folds of the Himalayas, extending in a north-west to south-east direction across Asia, forming a series of parallel ranges of great elevation, and also in the more or less latitudinal strike of the folds of older rocks of the Peninsula of India and of South Africa, the great river valleys of which two areas indicate this direction by their course. These palæozoic folds are traversed by folds (accompanied by local dislocations), running (nearly) in a north-south direction across the ranges, now deepened by the eroding agencies of glaciers and rivers, and which have shaped the beds of the palæozoic rocks into more or less dome-shaped masses, like so many enormous and inverted cups ranged side by side in the ranges of the Central Himalayas. Not less is it demonstrated by the direction and composition of the Burmese

[1] Palæozoische und mesozoische Flora des östlichen Australiens. In Palæontographica, Suppl. III, Lief. III, Hft. 4, 1879.

chain of hills, where we find Triassic marine beds immediately in rear of the advancing "landwave", which brought mesozoic forms of life to India from Australia.

It is at least probable that the later Carboniferous forms wandered westwards from Australia during Permian times and reached India in that epoch; in the wide basin-shaped folds of the crystallines and oldest palæozoic rocks of the peninsula great inland lakes were depositing material for ages during the whole of the middle and close of the palæozoic times. The same conditions but on an altered surface, still prevailed to a certain extent during the Permian times, for we see the oldest deposits of the incoming period deposited in wide and apparently open basins,—side by side with the basins of the palæozoic epochs. During the enormous periods of the Triassic and Rhætic times, when huge deposits of marine beds took place in the northern or Himalayan region, the same south-eastern pressure continued more or less, with the result of still more elevating and draining the peninsula, converting the lake-basins into great river valleys, at the same time depressing the Central Asian triassic sea, thus uniting the European (Alpine) with the Armenian (Asia Minor, Caucasus) with the Northern (Siberia) and Southern (Himalayan) basins, the deposits of which all show the most wonderful similarity of animal life which must have existed in those times.

Another link in the chain of evidences in this direction is the continuity of Mesozoic freshwater deposits of South and Central Africa, where we find the extensive Karoo series from the bottom boulder-beds (= Talchirs) to the topping sandstones of the Drakensberg mountains as nearly the same series, and containing similar species of fossil plants and terrestrial animals, as our own Gondwánas. Such an extensive rise of land may well correspond to a widespread triassic ocean extending over the north-western half of Asia and a great part of Europe.

After the deposition of the youngest members of the Rhætic or lower Lias, a change in the outline of the great southern continent takes place. Part of the present Indian ocean was formed, and the sea encroached along the western margin of the present peninsula, thus enabling the fluviatile deposits of the upper Gondwánas to mingle with the upper Jurassics of Cutch. Similar changes took place along the southern coast of Africa, *vide* the Jurassics of Uitenhage. Probably the great island of Madagascar is a standing monument of the former extent of the triassic continent of Gondwána-Karoo type. Extensive sandstone deposits fringing the crystalline centre are described to occur in the island.

Indeed, the partial disturbance of post-Liassic times corresponds with the reported overlap of the upper Gondwánas (Mahadevas) over the older Gondwánas, and also with the absence in the Central Himalayan area of the Lower Oolite; on the lowest Liassic beds (which possibly belong really to the upper Rhætics) follow immediately the Spiti shales of upper-middle Oolitic age.

10. *The lower Trias in the marine and in the continental regions.*—Long ago attention was directed to the Triassic deposits of the Alps by the excellent works of the Austrian geologists, being remarkable as containing a singular admixture of Palæozoic forms of life with Mesozoic types. This is especially the case in the oldest Trias beds,—in the so-called Werfen beds, which lately have been divided

again into two sub-groups, both of which I recognized in the Himalayas. These base beds really represent the Buntsandstein of extra-alpine areas, but have a wide extent, being now known over a great part of Armenia, the Caucasus, probably Siberia, and certainly the Tibetan area. In a paper in this number of the Records I give short descriptions of a few new forms of Cephalopods from this bed, along with a fragmentary notice of its fossil contents generally. Besides all the principal fossils characteristic of the Werfen beds of the Eastern Alps, I found associated with them numerous parent forms of Ammonite genera, later on developed in the Trias, and also an undoubted Productus, which most resembles the *Productus latirostratus*, Howse, of the Permian. It is therefore a bed containing an admixture of palæozoic forms with younger types, but the intimate relation with the overlying Trias and Rhætic is well proved by the constant appearance of these variegated shales and limestones at the base of the Muschelkalk, overlapping in succession the various beds composing the Carboniferous formation.

Turning to the Peninsula, we find in like manner the base-rock of the Gondwánas, represented by the Talchirs with Karharbari beds, containing (according to Dr. Feistmantel, who was the first who drew attention to this fact), besides the forms later on so common in the Gondwánas, species closely allied to, if not identical with, the younger Carboniferous plants of Australia. If it is at all possible to compare marine beds with fresh water deposits, then surely the comparison between the "Werfen beds" of the Himalayas with the Talchir-Karharbari beds afford many points of analogy: both are the first deposits which take place after the readjustment of physical conditions in postpalæozoic times, and both contain a mixture of younger palæozoic and of triassic types of forms. I have, therefore, referred both these groups to the same parallel in the annexed table.

11. *The Tertiary series of the Tibetan Himalayas.*—The cretaceous limestones mostly occupy the last range of hills, forming as it were a rim around the vast high plateau of Tibet; beyond is a wide expanse of Tertiary rocks, beyond which appears again the mesozoic section. I only examined the series as far as the Sutlej, which river flows through upper Tertiary deposits.

Leaning against the cretaceous series of the Tibetan passes, I found white and red limestones, with a few indistinct traces and sections of Nummulites, the whole traversed by enormous dykes of a basaltic trap, which has completely altered the rocks into a kind of semi-metamorphic mass, in some parts resembling a porphyry. Stoliczka has described the same occurrence in the north-western Himalayas.

Next follow pepper-and-salt coloured sandstones and grits of molasse appearance, which in all probability represent some member of the southern Siwalik belt. But only here and there the highly inclined lower Tertiaries are seen in the lower river valleys, the whole being covered up by the younger gravels and sands which spread in horizontal beds and widely extended terraces over the great Sutlej valley. I may here mention that in this latter deposit near Dongpa I found fragments of mammalian bones, which makes it tolerably certain that the former finds of bones (Strachey) were also derived from the same source.

It is, therefore, clear that there was a break and change of physical conditions; 1*st*, after the deposition of the Rhætic; 2nd, after the close of the Nummulitic epoch.

12. *The Indian Peninsula during the cretaceous and tertiary epoch.*—*a.* The "breaking down" in shoals of the Indian ocean must have continued for a long period; at least the patches of Jurassics and later on of cretaceous beds which penetrated far into the northern half of the Peninsula go far to prove great fluctuations during these times. The presence of remains of a marine cretaceous formation in the south-east of the Peninsula and narrow strips of similar rocks in the Khasia hills, taken in connection with such formation in the Punjab, clearly demonstrates the existence of bays to have existed east and west of the Peninsula during those epochs. It was then that the enormous and long continued pressure coming from the south and now coming from two directions, squeezing as it were the triangular Peninsula forwards and northwards, resulted in the great dislocations of the Himalayan area, which were afterwards developed and widened. The pressure coming from both sides, east and west, resulted no doubt in the bow-shaped outline of the mountain ranges with its convexity near the centre and directed southwards, at the same time dislocating and shattering part of the western limits and thus forming the foundation stones to the later formed Salt-range and neighbouring hills,—west and south-west of the present strike of Himalayan hill-ranges. Simultaneously with this great tension, igneous rocks were pushed up in the dislocations formed; we find such examples in the Silhet Jurassic trap, in the admixture of trappean matter in the Olive-shales of the Salt-range, and the similar trappean-like cretaceous shales and rocks of Tibet.

b. The tension must have continued long after the close of the cretaceous epoch and during the deposition of the tertiaries, during which time the enormous dislocations have formed along the Southern Alps,—the west coasts of the Apennine chains, and here along the greater part of the southern limits of the Himalayas, and lastly along or parallel to the west coast (or somewhere near it), of India,—probably the opening through which the great basaltic flows found an exit, which, both in India and Africa, Arabia and the intervening ocean, play such an important part. Similar to the Mediterranean dislocation, the Indian one is also still the seat of volcanic agency.

It is probable that during the early tertiary times the present Himalayan area consisted of a series of long islands, not unlike the lines of islands now seen in the eastern Archipelago, between which the Nummulitics were deposited; I believe this feature was really owing to a partial breaking down of the area. The basaltic traps which we find in the tertiaries of both sides of the Indian Himalayan axis are met with along the strike of the dislocations.

In the following table I have endeavoured to render the comparison of rocks as above demonstrated :—

Comparative Table of Indian Formations.

	Himalayas.	Peninsula.	South and Central Africa.
	Tertiary fresh water deposits.	Tertiary fresh water deposits.	Tertiary and recent formations.
	Break.	Break.	Break.
	Nummulitics and trap.	Nummulitics and trap.	
	Cretaceous and trap.	Cretaceous and trap (with inter-trappeans).	Cretaceous with trap.
Upper Jurassic	Spiti shales	Mahadevas (Cutch, near coast-line).	Sandstones, &c., of the Drakensberg, and Uitenhage Jurassics (coast).
	Gap.	Overlap.	
Lias ...	Lower Lias	Lower Gondwána series, (Barakars, Raniganj, and Panchets).	Karoo series.
Rhætic	Upper Kössen beds Megalodon-limestones, &c. Kössen beds Lower rhætic dolomites		
Trias ...	Upper } Trias Middle } Lowest Trias (Alpine Werfen beds).	Talchirs.	Boulder beds.
	Break.	Break.	Break.
Palæozoic rocks.	Carboniferous Devonian Lower Silurian Upper Cambrian } Continuous group of rocks, all fossiliferous.	Vindhian sandstones, &c. { Continuous group of sandstones, quartzites, &c., representing the whole of the post-Cambrian Palæozoic rocks.	Table-mountain sandstone and quartzites.
	Partial break.	Break.	Break.
	Lower Cambrian slates and quartzites.	Lower Cambrian? Sub-metamorphics, &c.	Devonian (marine) Silurian Slates, &c. } much contorted.
	Metamorphics.	Metamorphics.	Metamorphics.

PALÆONTOLOGICAL NOTES ON THE LOWER TRIAS OF THE HIMALAYAS, *by* C. L. GRIESBACH, F. G. S., *Geological Survey of India.*

Major-General R. Strachey, R.E., C.S.I., was the first to notice and describe[1] some of the grand sections through the Himalayas, and to draw attention to the existence in these snowy regions of triassic strata closely allied (as E. Suess has first shown)[2] to the Trias of the Eastern or Austrian Alps. As it has been my good fortune to have been sent to these lofty regions, I must here acknowledge the debt we owe to the learned General for having furnished such an excellent basis for further research in the most interesting region of the globe.

Having mapped the snowy ranges between the valleys of the Dhauli Ganga and Gori Ganga (Niti and Milam), I was able to collect a considerable material for description, but I must defer the detailed report on these noble sections, with maps, until after the next field season, when I hope to extend the survey to the frontiers of Nepál.

The great anticlinal fold of porphyritic gneiss with granite, termed by Stoliczka "Central gneiss" (by way of comparison with the so called "Central gneiss" of the Alps, a definition which has been given up long ago), is conformably overlaid by various metamorphic schists[3] and these again by the Palæozoic and following formations, a brief description of which I have given in the companion paper in this number of the Records. I will therefore only mention that on the eroded surface of the carboniferous rises the huge mass of the triassic and Rhætic strata. The Rhætic beds form high, nearly perpendicular cliffs with an undercliff of older rocks, comprising the whole Trias from the Alpine Werfen beds (Buntsandstein) to the Upper Keuper rocks, all of which are well shown in the natural profile of Plate IV; the proportions of thicknesses and the outlines of the cliff are absolutely correct, being drawn with the aid of a camera lucida, from an opposite height, about in a horizontal plain with the junction of the Rhætic and Trias.

In the following list I give a detailed enumeration of the beds composing both the Rhætic and the Trias, with their probable correlations :—

Upper Oolite (Spiti shales).

		THICKNESS. Ft.	In.
Lower Lias ...	1. Black shales and dark earthy limestone with oolitic structure, containing	13	0
Resembles the Grestener beds of the Eastern Alps.	*Belemnites bisulcatus*, Stol.		
	" *tibeticus*, "		
	" sp.		
	Ammonites annulatus, Sow. var.		
	" *davsei*, Sow.		
	Rhynchonella austriaca, Sss.		
	Thalassites depressus, Qu.		
	Ostrea, sp.		
	Pecten, sp.		
	Total ...	13	0

[1] Quart. Jour. Geol. Soc., Vol. VII, p. 292.
[2] Verh. Geol. Reichsanst. 1862, p. 258.
[3] *See* Text illustration, fig. 1, of my paper in this number of the Records, p. 84.

		THICKNESS. Ft.	In.
Rhætic ... Represents the Starhemberg facies of Kössen beds of the Alps.	1. Grey crinoid limestone, very hard, weathering brown, thick-bedded, with intercalated shales, full of fossils, and in many places made up entirely of them. Containing a mixture of true Rhætic and Liassic forms:	13	0
	Pecten bifrons, Salt.		
	„ *mayeri*, Winkl. (var.)		
	„ *lens*, Sow.		
	„ *corneus*, Gldfss. (non Sow.)		
	„ *cornatus*, Mün.		
	„ *valoniensis*, Defr.		
	Gervillia inflata, Schfl.		
	Plagiostoma herrmanni, Qu.		
	„ *giganteum*, Qu.		
	Pholadomya roemeri, Ag.		
	Myophoria cardissoides, Schl.		
	Cardium rhæticum, Mer.		
	Terebratula horia, Sss.		
	Rhynchonella fissicostata, Sss.		
Hauptlithodendron-limestone of Suess:	2. Grey *Lithodendron* limestone shewing sections of small shells on weathered surfaces	6	0
	3. Grey limestone with fossils as bed 1, and *Lithodendron*	5	0
with Kössen beds in following.	4. Dark grey sandstone-like crinoid limestone with numerous white calcspar veins	9	6
	5. Uneven shaly beds similar to (4)	3	0
	6. Dark grey crinoid limestone alternating with shaly beds	17	0
	7. Grey massive crinoid limestone	17	0
	8. Sandstone-like limestone, false-bedded, here and there shaly	2	0
	9. Dark brecciated limestone with crinoids ...	1	6
	10. Very hard grey crinoid limestone with *Lithodendron*	5	6
	11. Flaggy beds of crinoid limestone	2	3
	12. Brecciated bed, made up of angular pieces of dark limestone with a few rounded pebbles; thins out rapidly	0	8
	13. Crinoid limestone, locally as (12)	3	0
	14. Dark crinoid limestone in irregular beds with white calcspar veins	13	0
	15. Grey dolomitic limestone in beds of about 1½″ alternating with papery shales	2	6
	16. Dark grey sandstone-like crinoid limestone, top beds, shaly towards base, in thick masses ...	16	0
	17. Dark grey flaggy limestone (unfossiliferous) in beds of about 2″ to 5″, with shaly partings ...	7	0
	18. Brown shaly sandstone thinning out ...	0	5
	19. Flaggy limestone, vertically jointed ...	9	3
	20. Uneven sandstone bed	0	6
	21. Grey calcareous sandstone — with thin shaly partings.	0	6
	22. Grey limestone	0	9
	23. Grey calcareous sandstone	0	6

		Thickness. Ft.	In.
	24. Grey limestone flags with shaly partings ...	2	0
	25. " friable shales	0	6
	26. " limestone	0	9
	27. Friable grey needle-shales	0	2
	28. Grey limestone in massive beds with a few thin partings of shales	7	0
	29. Dark grey needle-shales, thin out and pass into limestone	1	2
	30. Thin flaggy limestone beds	0	6
	31. Dolomitic limestone	0	8
	32. Shaly limestone	2	4
	33. Crinoid limestone with some fossils (Kössen type)	1	0
	34. Sandy shales	1	8
	35. Crinoid limestone	0	5
	36. Papery sandy shales	0	2
	37. Brown calcareous sandstone (fossils)	0	7
	38. Crinoid limestone	0	4
	39. Shaly "	1	2
	40. " and papery calcareous beds	1	3
	41. Grey limestone	0	3
	42. Sandy shales	0	3½
	43. Crinoid limestone	1	0
	44. Papery calcareous shales	0	2½
	45. Sandstone shales	0	5
	46. Shaly crinoid limestone	0	8
	47. " and flaggy crinoid limestone	2	0
	48. Grey calcareous sandstone	0	4
	49. Shales	0	2
	50. Grey crinoid limestone	0	7
	51. Sandy shales	0	5
	52. Papery marly shales	0	10
	53. Grey limestone with shaly partings	0	10½
	54. Friable limestone shales	1	0
	55. Marly bed	0	8
	56. Irregular bed of grey limestone; thins out ...	1	3
	57. Flaggy limestone with shales	6	9
	58. Grey crinoid limestone with *Belemnites* ...	0	5
	59. Limestone flags with friable shales	4	0
	60. Crinoid limestone with *Pecten bifrons*, Salt ...	1	4
	61. Limestone flags and shales	2	4
	62. Shaly calcareous sandstone	2	9
	63. Crinoid limestone with a shaly parting ...	1	9
	64. " " with *Pecten bifrons*, Salt ...	3	0
	65. Dark limestone alternating with shaly crinoid beds	4	0
	66. " grey limestone, dolomitic, with shaly partings	35	0
	67. " fossiliferous crinoid limestone in massive beds	45	0
Dachstein limestone.	68. Grey earthy limestone full of *Myacites* sp. ...	7	0
	69. Hard limestone beds, containing many fossils, and on the weathered surfaces showing sections of large *Megalodon* sp.	35	0

		Thickness. Ft.	In.
	70. Hard crinoid limestone in thicker beds ...	7	6
	71. Dolomitic limestone	6	0
	72. „ „ in flaggy beds	3	6
	73. Massive grey dolomite, towards base rather flaggy	45	0
Hauptdolomit ...	74. „ dolomite, with scarcely any bedding ...	135	0
	75. As (74), but with partings of crinoid limestone ...	223	0
	76. Dolomite in beds of about 4 feet thickness towards base, reddish, and containing *Lithodendron* ...	98	0
	77. Dark concretionary limestone with reddish purple cellular Rauchwacke appearance here and there, in beds of 6 inches to 1 foot	5	0
	78. Crinoid limestone in thicker beds	11	0
Plattenkalk of Gümbel.	79. Dark dolomites in massive beds, the contact surfaces knitted together (resembling sutures, in the outcrop)	100	0
	80. Dolomites and limestone beds with "knitted" contact surfaces as (79), full of *Lithodendron*, and with a few shaly partings	48	0
	81. Massive beds of dark blue limestone and dolomite alternating with flaggy beds of limestone; the latter form about 12 feet of the upper part. Some masses of it of dark purple colour with crinoid sections	50	0
	82. Dark dolomites with calcspar veins	147	0
	83. „ „ flaggy beds and partings of shaly sandstone	241	0
	84. Dark hard concretionary limestone alternating with dolomitic beds	74	0
	85. Grey and reddish dolomites in perfectly inaccessible cliffs, about	700	0
	TOTAL ...	2,200	7½

As I intend to give here only a short description of the lowest members of the Trias, I will only say so much, that in the main the above Rhætic section corresponds exactly with the typical sections of that formation in the Austrian Alps, namely, we have here in descending order:—

1. Lithodendron-limestone, interbedded with limestone containing fossils belonging to the Alpine Kössen beds, which have been grouped into four horizons by Suess=Hauptlithodendronkalk with Kössen beds.
2. Thick-bedded limestones, here and there dolomitic, still with Lithodendrons here and there, and beds with Megalodon=Dachsteinkalk.
3. Great development of dolomites and flaggy limestones=Hauptdolomit with Gümbel's Plattenkalk.

The undercliff consists of a series of beds which represent the whole of the marine Trias beds of the Eastern Alps. The series rests on the denuded and rugged carboniferous quartzites, which again form a steep cliff falling almost vertically down to the base of the valley.

The detailed section of it is as follows :—

	UPPER TRIAS.	THICKNESS. Ft.	In.
Alps : Opponitzer beds.	... 22. Compact brown (liver-coloured) limestone, with rough contact surfaces; beds nearly of equal thickness, about 12 inches, and here and there separated by greenish-grey shales. Numerous bivalves, closely allied to	152	0
	Corbis mellingi, Hau. var.		
	21. Liver-coloured brown limestone, alternating with greyish-green shales, containing	29	0
	Corbis mellingi, Hau. var. *Orthoceras*, sp.		
	20. Earthy limestone with shaly partings ...	228	0
	19. Shaly limestone with earthy shales alternating ...	30	0
Alps :	*Spirifer lilangensis*, Stol. var.		
Lunzer and Partnach beds.	18. Shaly limestone and shales with hard concretionary limestone	22	0
	17. Greenish-grey shales	4	6
	16. Limestone with chert nodules	1	6
	15. Flaggy limestone	5	0
	14. Friable greenish-grey shales, weathering brown, with flaggy limestone alternating ...	31	0
	13. Marly friable shales	5	0
Alps :	... 12. Hard grey limestone	4	0
Hallstadt beds.	11. Hard grey limestone, weathering brown, rather silicious, containing nodules of white concretions with fossils : *Opis globata*, Dtm. *Acrochordiceras spinescens*, Hau. *Tropites ehrlichi*, Hau. var. *Feistmanteli*, n. sp. *Balatonites himalayanus*, Blfd.		
Alps : St. Cassian.	... 10. Grey earthy limestone beds, with marly and shaly partings, weathers brown.		
	9. Same as (10) with *Spirigera*, sp.		
	9, 10, and 11, total	275	0
	8. Greyish-green micaceous shales, a few plant impressions	160	0
	7. Shaly grey earthy limestone	38	0
Alps : ... Wengen beds and St. Cassian.	6. Dark splintery limestone flags with dolomitic beds and very scarce partings of black shales ...	76	0
	5. Black limestone beds in flags of about 6 inches thickness, which form groups of about 3 feet thickness, alternating with the same thickness of black splintery shales, with	152	0
	a species of the group of the *Amaltheidæ* *Halobia rarestriata*, Mojs. *Daonella tyrolensis*, Mojs. „ sp.		

		Thickness. Ft.	In.
	4. Dolomitic limestones in more massive beds, with few shaly partings	38	0
Alps: ... Wengen beds.	3. Shaly limestone with— ... ... *Daonella*, sp. *Spirifer lilangensis*, Stol. var.	38	0
	2. Thick-bedded shaly limestone with traces of fossils, mostly Ammonites	48	0
Alps: ... Buchenstein beds.	1. Black limestone flags of about 12 inches thickness, each alternating with black splintery shales of same thickness	103	0

LOWER TRIAS.

			Ft.	In.
II. VIRGLORIA LIMESTONE.	*b.* Reifling limestone (Alps).	122. Very hard grey concretionary limestone in massive beds with subordinate partings of dark shales containing many fossils very difficult to extract: about	50	0
		Orthoceras dubium, Hau. *Trachyceras voiti*, Opp. „ *thuilleri*, Opp. „ sp. *Arcestes diffissus*, Hau. *Ptychites gerardi*, Blfd. *Pinacoceras floridum*, Wulf. *Pecten*, sp. *Myoconcha*, sp. *Pleurotoma sterilis*, Stol. *Reptilian bones.*		
	a. Recoaro-limestone (Alps).	121. Earthy-grey limestone, towards base somewhat shaly:	3	0
		Rhynchonella semiplecta, Mün., var. „ *salteriana*, Stol. } in great numbers.		
I. WERFEN BEDS	*b.* Campiler beds ... (Alps).	120. Hard grey splintery limestone ...	0	8
		119. Dark friable clayshales, weathering variegated	0	3
		118. Limestone	0	4
		117. Limestone with shaly partings ...	1	6
		116. Limestone	0	1
		115. Shales	2	0
		114. Limestone	0	7
		113. Shales alternating with 12 thin beds of limestone	1	0
		112. Limestone	0	6
		111. Shales	0	4
		110. Limestone	0	3½
		109. Shales with limestone partings ...	1	2
		108. Limestone	0	6
		107. Shales, alternating with 11 limestone	2	0
		partings	2	

			Thickness. Ft.	In.
I. WERFEN BEDS.—*contd.*		106. Limestone	0	8
		105. Shales	0	10
		104. Limestone	0	6
		103. Shales with 5 limestone partings ...	0	11
		102. Limestone	0	5
		101. Shales	0	7
		100. Limestone	0	7½
		99. Shales	0	6
		98. Limestone	0	7
		97. Shales and limestone partings ...	1	2
		96. Limestone	0	8
		95. Shales	0	7
		94. Limestone	0	4
		93. Shales	0	7
		92. Limestone	0	9
		91. Shale with 10 limestone partings ...	1	4
		90. Limestone	0	7
	Salt-range: Zone of *N. planulatus*, DeKon.	89. Shales and limestone partings ...	0	10
		Norites planulatus, DeKon.		
		88. Limestone	0	6
		87. Shales with limestone parting ...	0	1
		86. Limestone	0	2
		85. Shales with 2 limestone partings ...	0	8
		84. Limestone	0	5
		83. Shales	0	3
		82. Limestone with one shaly parting ...	0	4
		81. Shales with two limestone partings	0	6
		80. Limestone	0	3
		Monophyllites wetsoni, Opp.		
		79. Shales	0	5
		78. Limestone	0	5
		77. Limestone with three shaly partings	0	6
		76. Limestone...	0	5
		75. Limestones with 17 shaly partings	1	7
		74. Shales	0	2
		73. Limestone	0	6
		72. Shales	0	½
		71. Limestone	0	2
	Salt-range: zone of *Ophiceras lyellianum*, DeKon.	70. Shales with	0	1½
		Ophiceras tibeticum, n.s.		
		69. Limestone...	0	½
		68. Shales	0	2
		67. Limestone	0	1
		66. Shales	0	1
		65. Limestone...	0	1
		64. Shales	0	1
		63. Limestone	0	4
		62. Shales	0	½
		61. Limestone	0	1
		60. Shales	0	2
		59. Limestone	0	3
		58. Limestone with 6 shaly partings ...	0	6

		Thickness. Ft.	In.
	57. Limestone	0	2
	56. Shaly limestone	0	1½
	55. Shales	0	1
	54. Limestone with 2 shaly partings ...	0	5
	53. Limestone with shales	0	3
	52. Limestone	0	5
	51. Shales	0	½
	50. Limestone	0	1
	49. Shales and limestone	0	2⅓
	48. Shales	0	2⅓
	47. Limestone	0	3
	46. Shales	0	2
	45. Limestone	0	2½
	44. Shales	0	1
	43. Limestone	0	3
	42. Shales with a thin bed of limestone	0	5
	41. Limestone with 9 shaly partings ...	1	3
	40. Limestone	0	1
	39. Limestone	0	3
	38. Limestone with 14 shaly partings ...	1	2
	37. Limestone	0	2⅓
	36. Shales	0	2
	35. Limestone with shaly partings ...	0	3½
	34. Shales	0	1
	33. Limestone with 3 shaly partings ...	0	5
I. WERFEN BEDS.—*contd.*	32. Shales	0	2
	31. Limestone	0	2
	30. Shales	0	3
	29. Limestone	0	2⅓
	28. Shales	0	2
	27. Limestone	0	1⅓
	26. Shales	0	1½
	25. Limestone	0	1
	24. Shales	0	1⅓
	23. Limestone	0	2
	22. Shales	1	0
	21. Limestone	0	3
	20. Shales	0	1
	19. Limestone	0	3
	18. Shales	0	4
	17. Limestone	0	3
	16. Shales	0	10
	15. Limestone with shaly partings ...	1	6
	14. Limestone	0	6
	13. Shales	1	0
	12. Limestone	0	3½
	11. Shales with 11 thin layers of hard splintery limestone ...	0	4½
	10. Limestone	0	3
	9. Shales with limestone (1″) towards top with— *Otoceras woodwardi*, n.s.	5	0

			Thickness. Ft.	In.
I. Werfen beds.—*concld.*		8. Limestone	0	2
		7. Shales	0	5½
		6. Limestone with— ... ... *Xenodiscus gangeticus*, DeKon. " *buchianus*, "	0	3
	Salt-range, zone of *Ptychites lawrencianus*, DeKon. *Xenodiscus demissus.* " *gangeticus.*	5. Variegated papery shales ...	0	6
		4. Limestone with— ... ... *Avicula venetiana*, Hau. *Myophoria ovata*, Br. *Posidonomya angusta*, Hau. *Otoceras woodwardi*, n.s. *Xenodiscus demissus*, Opp. " *gangeticus*, DeKon.	0	4
		3. Friable, papery shales with a parting of limestone (1″) with— ... *Otoceras woodwardi*, n.s.	0	9
		2. Dark grey limestone with shaly layers with— ... ... *Posidonomya angusta*, Hau. *Gervillia mytiloides*, Schlot. *Modiola triquetra*, Seeb. *Myophoria ovata*, Gdfss. *Avicula venetiana*, Hau. *Bellerophon*, sp. *Nautilus brahmanicus*, n.s. *Otoceras woodwardi*, n.s. " " var. *undulatum*, n.s. *Ptychites lawrencianus*, DeKon. *Ophiceras medium*, n.s. " *himalayense*, n.s. " *tibeticum*, n.s. " *densitesta*, Waag., var. *Xenodiscus gangeticus*, DeKon. " *buchianus*, " " *demissus*, Opp. *Trachyceras gibbosum*, n.s.	0	5
	b. Campiler beds ... (Alps).			
	a. Seiss beds (Alps) Salt-range Productus beds.	1. Dark, carbonaceous, crumbling shales, micaceous, weathering in reddish and deep-brown tints, giving it a variegated appearance, with a few thin beds of hard grey limestone. The general character of these shales is the same as of all the intercalated beds of shales of the beds above ... It yielded— *Monotis claræ*, Emmr. *Productus latirostratus*, Howse, var. *Arcestes* sp.	127½	

The whole rests on the carboniferous series.

The above list of beds, it will be seen, corresponds in a marvellous degree with the beds of the Trias as developed in the Eastern Alps, and the order stands therefore as follows :—

The Trias in the Himalayas.

	Character of rocks.	Zones.	Correlation with horizons in the Eastern Alps.	Trias in Germany.
UPPER TRIAS.	6. Liver-coloured limestone with greenish shales.	*Corbis mellingi*, Hau. var.	Opponitz and Raibl.	Keuper.
	5. Friable shales and earthy beds.	*Spir. lilangensis*, Stol.		
	4. Limestone .	*Tropites ehrlichi* .	Hallstadt and	
	3. Earthy beds and shales	……	St. Cassian.	
	2. Black limestone and dolomites.	*Daonella tyrolensis*, Mojs.	Wengen.	
	1. Black limestone flags and splintery shales.	Brachiopods . .	Buchenstein.	
LOWER TRIAS.	4. Hard grey concretionary limestone.	*Ptychites gerardi*, Blfd.	Reifling limestone. } Vìrgloria limestone	Muschelkalk.
	3. Earthy limestone .	*Rhynchonella semiplecta*, Mün., var.	Recoaro limestone.	
	2. Limestone and shales.	*Posidonomya angusta*, Hau.	Campiler beds } Werfen beds.	Buntsandstein.
	1. Dark shales, etc. .	*Monotis claræ*, Emm.	Beds of Seiss	

As far as is known at present, this succession of horizon holds good in India over a considerable area, to judge from certain beds, which have been found in other parts of our Himalayas. The lower group has been described by Stoliczka from the north-west Himalayas (Spiti), but he considered only the upper part of the Lower Trias as such, with *Rhynchonella salteriana*, Stol., and *Ptychites gerardi*, Blfd. He certainly came across the lower group, but in the absence of known Trias fossils he represented it as upper carboniferous, containing numerous *Productus semireticulatus*, Mart. (sp.), *Spirifer rajah*, Dav. I have compared some of his original specimens with my own collection, and have no doubt that the beds are quite identical both in lithological character and probably in their fossil contents.

It might be urged that the presence of the Productus speaks for a Permian age of these deposits; but taking into consideration the fact that stratigraphically the complex of Trias beds is a connected series of deposits without any interruption, with the greyish black shales invariably at their base, the whole resting on

a rugged and denuded surface of the carboniferous quartzite, it must be admitted that on this account alone the shales (Kuling shales of Stoliczka) must be included amongst the Triassic group. These shales resemble the Werfen beds of the Alps, not only in lithological character, but also in the fact that here as there they contain a number of older forms of life side by side with new arrivals. Such is, it appears, the case with the Werfen beds of Armenia[1].

The following forms of the 1st and 2nd groups of the lower Trias are identical with such of the Werfen beds of the Alps:—

Monotis claræ, Emm.
" *angusta*, Han.
Gervillia mytiloides, Schl.
Modiola triquetra, Seeb.
Myophoria ovata, Gdf.
Avicula venetiana, Hau.

Nearly identical with a Hallstadt form is *Ophiceras* (*Amm.*) *densitesta*, Waag.[2] All the other species represent earlier stages of forms found also in the triassic beds of the Eastern Alps.

So for instance:—

Otoceras woodwardi allied to { *Hungarites* (?) *Strombecki*, Griep.
" *scaphitiformis*, Hau.
" *salaensis*, Bökh. }

Ophiceras tibeticum, n.s., allied to *Lytoceras simonyi*, Hau., and other *Lytoceratites*, occurring in the Lower Trias.

DESCRIPTION OF NEW SPECIES.

Class: CEPHALOPODA.

Order: TETRABRANCHIATA.

Family: *NAUTILIDÆ*

Genus: NAUTILUS.

NAUTILUS QUADRANGULUS, Beyr., *var.* BRAHMANICUS, n. s. Plate I, figs. 1—3.

This species is most nearly allied to the Liassic forms, of which *N. aratus*, Schl., is the representative. The shell is considerably involute, the umbilicus deep. The ventral side flattened, the section of the shell sub-angular. The descent to the umbilicus is vertical and sharply defined. Five radial lines of growth are visible, and a few broad indentations at intervals of about $\frac{3}{4}$ inch along the last chamber indicate a faint kinship of this form to *Nautilus fugax*, Mojs.[3] Towards the mouth the shell opens out, trumpet-shaped. What remains of the last

[1] Abich: Geol. Forschungen in den Kaukas. Ländern, 1st. Theil, Wien, 1878. *See* also Mojsisovic's Verh. Geol. Reichsanst., 1879, p. 171.
[2] Benecke's Geog. Pal. Beiträge, I, p. 369.
[3] Jahrb. k. k. Geol. Reichsanst., 1869, Pl. XIX, fig. 3.

chamber amounts to exactly one-half of the entire evolution. Siphon situated at about ¾ of the height (fig. 3). The septa show nearly the same lines as *Nautilus subaratus*, Keys.;[1] the pointed antisiphonal lobe marks this species at once as belonging to the forms of which *N. aratus*, Schl., is the type. The number of septa are about thirty in a whorl.

The only character which distinguishes this species from Beyrich's species *N. quadrangulus*[2] is the fact, that the German Muschelkalk form seems more compressed than our species, so far as I can judge from the figure given. But there can be no doubt that the German Muschelkalk species is a descendant of this lowest Trias form.

Likewise *Nautilus spitiensis*, Stol., is probably also only a later stage of development of this species, which is common in the Werfen horizon of the Tibetan Himalayas.

With the exception of the angular shape of the section of the whorls which is so marked in the Indian species, it agrees very nearly with *Nautilus subaratus*, Keys., both in general shape and course of the lobe line. In fig. 2 I have shown another specimen, which I cannot separate at present from the larger form in spite of the indication of a hexagonal outline of the section of the mouth as shown in the figure. It is probably only a younger individual of the same species.

It is very numerous in Bed 2 (horizon of *Posidonomya angusta*, Hau.) of the lowest Trias.

Class: CEPHALOPODA.

Order: ?

Family: *AMMONITIDÆ.*

Tribe: PINACOCERATIDÆ.

Genus: OTOCERAS, n. g.[3]

Amongst the numerous forms found in Bed 2 (horizon of *Posidonomya angusta*, Hau.), one of the most remarkable groups is that for which I propose the above name. Occurring, as they do, in a bed belonging to the lowest Trias, they form the connecting link of a group of forms, the first of which appear in the palæozoic epoch.

The earliest species belonging to the tribe of *Pinacoceratidæ* appear in the Devonian, where we find the *Sageceras sagittarius*, Sandb.

In the Permian of Armenia we find again several species, and representatives of it are found in India (Salt-range) and pass on into Upper Trias, where many species belong to that genus.

The species described under the above generic name appear in the lowest Trias as companions of a number of early Triassic types, in the same bed with

[1] Middendorf's Reise in Sibirien, Pl. IV, fig. 3.
[2] Abh. Akademie, Berlin, Pl. III, fig. 5.
[3] Οὖς, ὠτός = ear.

Pos. angusta, Hau. Though it seems that there are several varieties, if not species, amongst the numerous specimens obtained, I prefer to include them for the present under one collective name.

OTOCERAS WOODWARDI, nov. spec. Plate I, figs. 4 & 5, and Plate II.

Shell involute, with very deep umbilicus, with rapidly increasing outer whorls. The part of the shell nearest the umbilicus bulged out into an ear-like shape, giving the section of the shell (Plate I, fig 4*a*,) a more or less rhomboidal aspect.

It is very probable that the last whorl in adult individuals covered and enclosed the entire shell. In all the specimens which I collected there is a tendency to enlarge the latter whorls at the expense of the umbilicus. The sides of the shell are only slightly curved and slope towards the sharp knife-like siphonal side enclosing an angle of about 67°. The compressed siphonal side is one of the most characteristic features of this species. In one of the adult specimens (Plate I, fig. 4), this part of the shell has quite the appearance of a sharp knife, and only a faint indication of a three-edged termination is visible, whereas in some of the younger specimens (Plate II, figs. 1 and 3) and even in the older form (Plate II, fig. 2*a*) the tripartite character of the siphonal side is strongly marked. This character alone would stamp this species as belonging to *Hungarites*, Mojs.,[1] of which *H. scaphitiformis*, Hau.,[2] and *H. zalaensis*, Böckh.,[3] are the types, but the shape of the ear-like prolongation of the sides of the shell near the region of the second side-lobes is a character entirely absent in the Austrian genus. A line connecting the ear-like prolongations of the sides, or, in other words, the second side-lobes, will intersect the median plane in a point, from which to the siphonal margin of the preceding whorl is about the third of the entire distance between the point of intersection and the siphonal margin of the outer shell. A vertical projection of the inner margin of the first lateral saddle to the median plane will intersect that plane in the siphon of the preceding whorl.

From Plate I, fig. 4*a*, it will be seen that the proportion in the increase of lateral expansion of the last whorl increases rapidly at the expense of the increase to the height of the shell, and it is not at all improbable that, as I said above, the final chamber inclosed nearly the whole of the shell in adult specimens, which character is indicated in fig. 3 of Plate II, which shows the almost vertical sides of the umbilicus, but since drawing the plates I have worked out of some blocks of stone the fragment of a larger specimen, showing part of the last chamber with the umbilicus. The latter is very narrow and closing in towards the outer side. The shell is extremely thick near the ear-like prolongation in the umbilical region and covered with wrinkles. The shell is covered with fine wavy lines of growth S-shaped, slightly bent forward near the siphonal margin.

The lobes show some variation, mainly in the auxiliary ones, but these increase in number with the successive whorls in the same specimen. As shown in

[1] Verh. Geol. Reichsanst., 1879, p. 140.
[2] Denksch. Akademie Wiss., Wien, 1855, Pl. III, fig. 4.
[3] A. M. K. Földtani intézet, Pest, 1872, Pl. VII, figs. 1 and 2.

the drawings of lobes in Plate II, this species possesses a broad siphonal lobe ending on both sides of the semicircular siphonal saddle in a sharp point. The external saddle (fig. 1*b*) is moderately high and a little narrower than the siphonal lobe. The first lateral lobe is the deepest of all, of the same width as the external saddle, and at the base shows plainly a tripartite arrangement of the serration.

I remarked also that the corresponding lobes vary on each side of the specimen (fig. 1). Whilst the first lateral lobe of the left side shows plainly this tripartite arrangement of serration, those on the right side have an additional sharp point added to the lower margin of the lobe as shown in fig. 1*b*. The larger specimen, fig. 4, shows a still more complicated serration of this lateral lobe, similar also in figs. 3 and 5. There follows in all specimens a very large first lateral saddle, slightly bent towards the inner side, with following rather narrow second lateral lobe, serrated at the base, this serration varying in the different specimens. The second lateral saddle is only half as high as the first and great lateral saddle, rather wider in proportion to its height, and followed by one or two auxiliary lobes of varying course. In some specimens the first auxiliary lobe reaches only half down the rounded and broad second lateral saddle and is not serrated at the base and might be described as a rudimentary lobe; in others, figs. 2*b*, 4 and 6, the auxiliary lobes and saddles are similar in shape to the last lateral lobe and saddle, decreasing in size as they near the ridge (r), noticed above. Beyond this the sutural line runs in a series of rudimentary lobes and saddles to the sutural margin (s), where it forms a flat serrated lobe; on the antisiphonal side I noticed on prepared specimens (fig. 6) a saddle, as broad as high, sloping towards the margin (s) followed by a narrower but deeper lobe, serrated at base, and a second higher and wider saddle, similarly sloping towards the marginal side. The antisiphonal lobe is bipartite.

Locality.—South of Rimkin Paiar and north of Kiunglung encamping ground, head-waters of the Ganges river.

OTOCERAS WOODWARDI, var. UNDATUM, n. s. Plate I, fig. 5.

With the first described specimens and only at one locality were found a few individuals agreeing in general shape and lobes with *Otoceras woodwardi*, but, unlike even the larger specimens of this species, showing very marked wavy ribs, only very slightly bent forward near the siphonal margin, but swelling out near the middle of the side of the shell. As none of the other specimens show this character, I have thought best to separate it for the present as a variety of the other form.

Locality.—South of Rimkin Paiar, east slope of the Kurgudthidhar mountain.

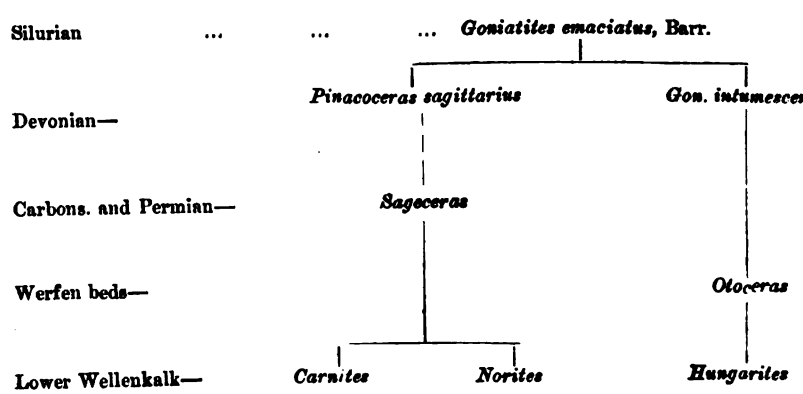
Allied forms.—The ancestors of the forms above described must be sought for in the family of the *Pinacoceratidæ*, Mojs., the oldest known ones of which occur in the Devonian of Oberscheld, *Pinacoceras sagittarius*, Sandb.[1] That *Sageceras*, known from the Permian and which like *Pinacoceras* lived up to the

[1] Sandberger: Schichtensystem in Nassau, p. 77.

Upper Triassic times, is a descendant from *Pinacoceras* is probable. There is another form which bears close resemblance to *Otoceras*, *Goniatites intumesens*, Bey.[1] var. *acutus*, which is a close relation of it and belongs to the Devonian system. In external shape, thickness of shell, fine lines of growth and the sharp-edged siphonal margin, they are all but identical, and from the figure (1*a*) it seems as if this species also, in a rudimentary stage, possessed the ear-like prolongations of the shell near the umbilical region. Turning to the lobes we find also the first lateral saddle largely developed and turned towards the umbilicus, and an indication of a second lateral saddle, but the lobes terminate in simple sharp points only, though corresponding in general proportion. The line of projection of the preceding siphonal margin (vertical to the median plane) cuts through the second lateral lobe near the inner margin of the great first saddle. We have here the true predecessor of *Otoceras* in Devonian beds.

The next younger form known is *Hungarites* (*Ceratites*) *strombecki*, Griep.[2] from the lowest Wellenkalk of Brunswick, which shows many characteristics of my genus, but most so in the form of the lobes (fig. 3) which are nearly identical with mine. Apparently also the projection of the siphonal margin of the preceding whorl passes through the second lateral lobe.

Whether the genus *Hungarites*[3] is a further development of *Otoceras* is not quite clear to me, but the description of the lobes given by J. Böckh[4] seems to point to a relation with the older form of *Otoceras*. Mojsisovic[5] hints at the possible derivation of *Pinacoceras* from *Goniatites emaciatus*, Barr.,[6] and indeed this species shows even greater likeness in general form and arrangement and position of the lobes to *Goniatites intumescens*, Bey., so that there is the indication of a pedigree, which would stand thus:



[1] Sandberger's Verst. Rhein. Schichtensyst., Taf. VII, fig. 1.
[2] Zeitsch. Deutsch. Geol. Gesellsch., Taf. VII.
[3] Verh. Geol. Reichsanst., 1879, p. 140.
[4] Földtani intézet, 1873, p. 156.
[5] Abh. Geol. Reichsanst., Bd. VI, p. 43.
[6] Syst. Sil., Vol. II, Pl. III.

PTYCHITES LAWRENCIANUS, DeKon.: Quart. Journ. Geol. Soc., Vol. XIX, Pl. VI, fig. 3.

As such I determine a few not well preserved specimens. They agree very well in general shape and in the formation of lobes with the Salt-range species, but with this exception, that my specimens exhibit traces of an ear-like ridge near the umbilical margin, thus showing some kinship to *Otoceras woodwardi*. Further researches in the Himalayas may reveal better specimens.

Of older forms the most nearly allied are *Goniatites hœninghausi*, Von Buch,[1] *G. intumescens*, Bey., var. *intermedius*, Sandb.,[2] and *G. buchii*, Vern.,[3] thus showing in some degree a derivation from the early types of *Otoceras*, and itself representing a predecessor of the later *Ptychites* forms of the Muschelkalk.

Genus: NORITES.

NORITES PLANULATUS, DeKon., var.: Quart. Journ. Geol. Soc., Vol. XIX, Pl. V, fig. 1.

My species differs somewhat from DeKoninck's figure, in that the ribs on the sides of the shell are more strongly marked and seem indeed to form tuberculous masses; the siphonal part is perfectly flattened, and resembles in that *Norites gondola*, Mojs. This species is common in the higher beds (89) of the Campiler group of the lower trias.

There is an excellent predecessor to this species found in *Goniatites tenuistriatus*, Vern.[4]

Tribe: LYTOCERATIDÆ.

Genus: OPHICERAS.[5]

Under this generic name I propose to unite forms which possess the external characters of the *Lytoceratidæ*, but possess a much simpler lobe-line even than *Monophyllites*, and must be considered as an older stage of development of the *Lytoceratites*, which appear first in the Muschelkalk. For the description of the generic characters I refer to *Ophiceras tibeticum*, n. s., which may be looked upon as the type of my genus.

OPHICERAS TIBETICUM, n. sp. Plate III, figs. 1 to 7.

Shell compressed, section of whorls oval and widening near the umbilicus (see figs. 2 and 3); the latter large and shallow. The shell with seven to nine whorls, each covering a little more than a third of the preceding one. The shell is thick, especially so near the umbilicus, and covered with fine wrinkles or lines of growth S-shaped and bent forward near the siphonal side (figs. 4 and 5) In the body-chamber, they assume the character of fine S-shaped ribs (fig. 6), resembling in that stage the ribs of *Lytoceras simonyi*, Hau., with which species my form corresponds in many characters. At irregular intervals the shell swells into rounded bumps, largest near the umbilical margin. The siphonal side is rounded,

[1] Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXV, fig. 7.
[2] Rhein. Schicht. Syst., Pl. VII, fig. 2.
[3] Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXVI, fig. 1.
[4] Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXVI, fig. 7.
[5] Οφις = serpent.

and the wrinkles or folds run across it and join with those of the other side. In a larger fragment of a body-chamber, which I refer to this species (fig. 1), the back is smooth, and the wrinkles or folds show only near the umbilical side.

The lobes are simple; the projection of the preceding whorl intersects the second lateral lobe near the outer wall of the second lateral saddle; the siphonal lobe is much wider than high, with a moderately high siphonal saddle, separated by the siphon. The external saddle is about as high as wide. The first lateral lobe is very deep and narrow, followed by a high first lateral saddle, bent inwards. The second lateral lobe is narrow and reaches only half as low as the first one. The second lateral saddle resembles in shape and height the first one, followed by a lobe of about the same depth as the last one, situated at the umbilical margin. The internal sutures are very simple. A deep bipartite antisiphonal lobe is accompanied by a rounded low saddle on each side. The margins of all the saddles are entire and the arches of the lobes very finely serrated, and in younger specimens and the inner whorls of others, often entire. Some fragments of young individuals resemble in general shape this species, but show slight deviations in the lobe-line (fig. 7).

Both in general shape and number, and arrangement (though not shape) of the lobe-lines, this species closely resembles the Lytoceratite genera (*Monophyllites* and *Phylloceras*) of the Muschelkalk and Hallstadt respectively, and may be said to be an earlier stage of these forms.

The earliest appearance of a form belonging to the chain of which the above species is only a link may be said to be *Goniatites bohemicus*, Barr., from the Silurian, and can be traced through a variety of allied species to the Devonian of Nassau, where we find in *Goniatites æquabilis*, Beyr., an exact likeness of our Himalayan species. Both section of shell[1], general characters and striation, agree perfectly, and there is a strong resemblance even in the lobe-line. The external saddle is rudimentary, as is also the second lateral saddle, which is moved nearer the umbilical margin. But there, as in our species, we find a strongly developed and large first lateral lobe, with a bend towards the inner side, closely resembling the later Himalayan species. We have here connecting links of a long chain of forms beginning already in Silurian times and reaching probably high up in the cretaceous series, thus:

Silurian: *Goniatites bohemicus*, Barr., etc. etc.

|

Devonian: *Goniatites æquabilis*, Beyr.

|

Lower Trias: *Ophiceras*, etc. etc.

|

Muschelkalk: *Monophyllites*.

|

Hallstadt: *Phylloceras*.

etc. etc.

[1] Sandberger's Rhein. Verst., Taf. VII, fig. 10.

OPHICERAS HIMALAYANUM, nov. sp. Plate III, fig. 8.

Shell rather less evolute than in the last described species, the last whorls rapidly increasing in height, and in that resembling more the *Lytoceras simonyi*, Mojs., even than the last species. But both the sculpture of the shell and the lobes differ considerably from *Ophiceras tibeticum*. There are a number of nearly straight, only sightly S-shaped, ribs running across the sides of the shell, which near the commencement of the body-chamber (indicated by a small arrow in fig. 8) almost disappear and change into irregular fine wrinkles and bumps near the umbilical side. What remains of the body-chamber is about one-half of the entire whorl. The siphonal side is rounded, the umbilical margin sharply defined, descending straight down towards the shallow and wide umbilicus. The lobes are identical with those of the following species (figured in fig. 9*b*).

OPHICERAS MEDIUM, nov. sp. Plate III, fig. 9.

General proportions of the shell the same as those of the last described species, but the shell is nearly smooth and only shows slight radiating wrinkles, which disappear entirely towards the siphonal side and are only slightly bent forward in that region. The lobe-line, fig. 9*b*, resembles more that (fig. 7) which I considered as a younger individual of *tibeticum*, n. s. The siphonal lobe ends in two sharp points on each side of the divided siphonal saddle; the external saddle is a simple arch, rather wider than high, followed by a narrower, very finely serrated (at the base) first lateral lobe. The first lateral saddle is wider than high and bent towards the umbilical side. The second lateral lobe does not reach so far down as the first, is narrower, but also very finely serrated at the base. The second lateral saddle is low and broad, and reaches over the umbilical margin; on the antisiphonal side I noticed a deep and bipartite antisiphonal lobe with a rounded saddle on each side connected with the second lateral saddle by a finely serrated lobe-line, representing one or more auxiliary lobes.

MONOPHYLLITES WETSONI, Opp., Pal. Mitth. Plate LXXXVI, fig. 2.

Agrees well with Oppel's figure, both in outward appearance and course of lobe-line. It was found only in fragments, but is very common in the upper beds of the lowest Trias group—the Campiler beds of the Alps.

TRACHYCERAS (?) GIBBOSUM, nov. sp. Plate III, fig. 10.

With the above forms occurs an Ammonite, which in outline resembles somewhat *Trachyceras (Amm.) semipartitum*, Von Buch[1], but the latter is involute in a higher degree than my species, and consequently developes several auxiliary lobes which are wanting in our species. I have at present referred this form to *Trachyceras*, but it is very probable that it represents a connecting link between *Ophiceras*, n. g., and *Xenodiscus*, Waag., as exemplified in *X. gangeticus*, DeKon., and *Buchianus*, DeKon., which I venture to include in Waagen's new genus.

[1] Über Ceratites Akad. Wiss., Berlin, 1849, Pl. III.

T. gibbosum is moderately involute, leaving a wide and shallow umbilicus; the shell is thickest, near the middle of the sides, in the region of the "bumps," which occupy exactly the centre-line of the sides, and are about six in number in the last whorl. The inner whorls are quite smooth, and on the surface of the shell itself neither ribs nor striæ are visible. The section of the mouth is oval, widest about halfway up the sides. The siphonal side is perfectly rounded. The body-chamber, as far as it is preserved, amounts to about half a whorl (the arrow indicates the commencement of it, fig. 10).

The lobes are very simple and resemble those of *Ophiceras medium*, n. sp., and partly also those of *Trach. semipartitum*, v. Buch. Besides the low siphonal lobe there are one external and two lateral lobes with one auxiliary lobe, which is situated near the umbilical margin. The antisiphonal lobe is deep and ends in two minute points (fig. 10*b*).

Tribe: **AEGOCERATIDÆ**, Waag.

Genus: XENODISCUS, Waag.

XENODISCUS DEMISSUS, Opp.

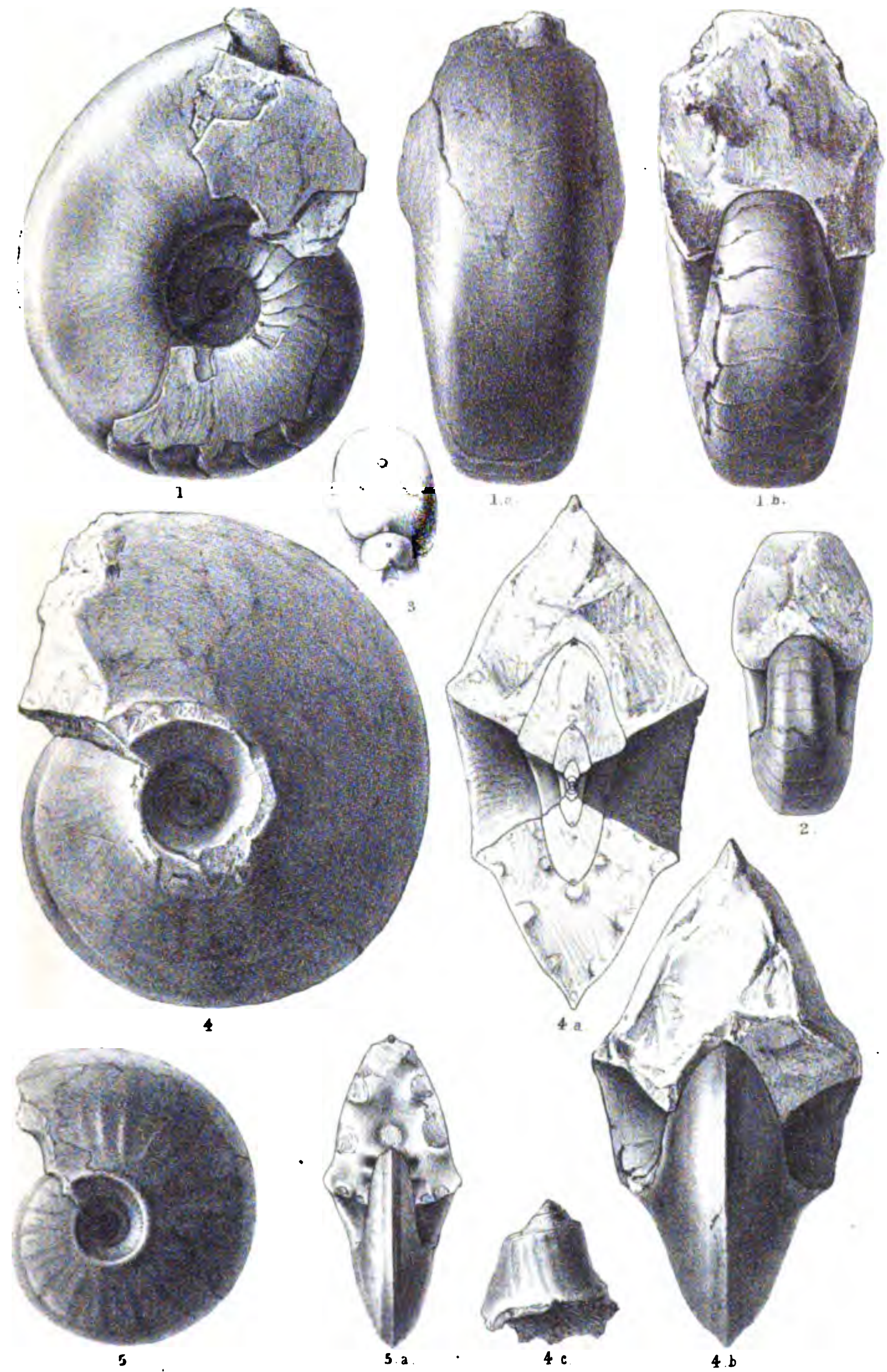
1862. ***Ammonites demissus***, Opp.: Pal. Mitlh., Taf. 86, fig. 1.
1872. ***Ceratites carbonarius***, Waag.: Mem. Geol. Surv., India, Vol. IX, Pl. I, figs. 2 & 3.
1879. ***Xenodiscus carbonarius***, Waag.: Palæont. Ind., Ser. XIII, Pl. II, figs. 2 to 5.

With the species above described and in the same bed (2) with *Posidonomya angusta*, Hau., and other Werfen bed fossils, occur numerous specimens belonging to a chain of forms which might be roughly described as beginning with the flat and characteristic *Xenodiscus demissus*, Opp., and ending with *Xenodiscus (?) buchianus*, DeKon.

I have nothing to add to the description of the above-named species after the excellent exposition given by Waagen in the Palæontologia Indica, but may add, that there can be no doubt that Oppel's figure agrees with Waagen's species, as it does with my specimens. The species is so common in bed 2, that necessarily there is a great variety of forms, all, however, agreeing in the principal characters. They show greatest variation in the ribs or wrinkles of the shell, to which I may add that the shell itself is rather thick, especially so half-way up the flattened sides, and is covered by wrinkly lines of growth, which at intervals develope into ribs.

It is possible to arrange from amongst them a complete chain, passing from the evolute specimens (representing Oppel and Waagen's species) up to considerably involute varieties, and in that stage closely resembling the two species of DeKoninck's *Goniatites gangeticus* and *Cer. buchianus*.

Though Dr. Waagen does not say so in his description of the new genus, I presume that *Xenodiscus* is really the early stage of development of *Aegoceras*, Waag., and stands in the same relation to the latter genus as does *Otoceras* and *Ophiceras*, respectively, to *Pinacoceras* and *Lytoceras*.



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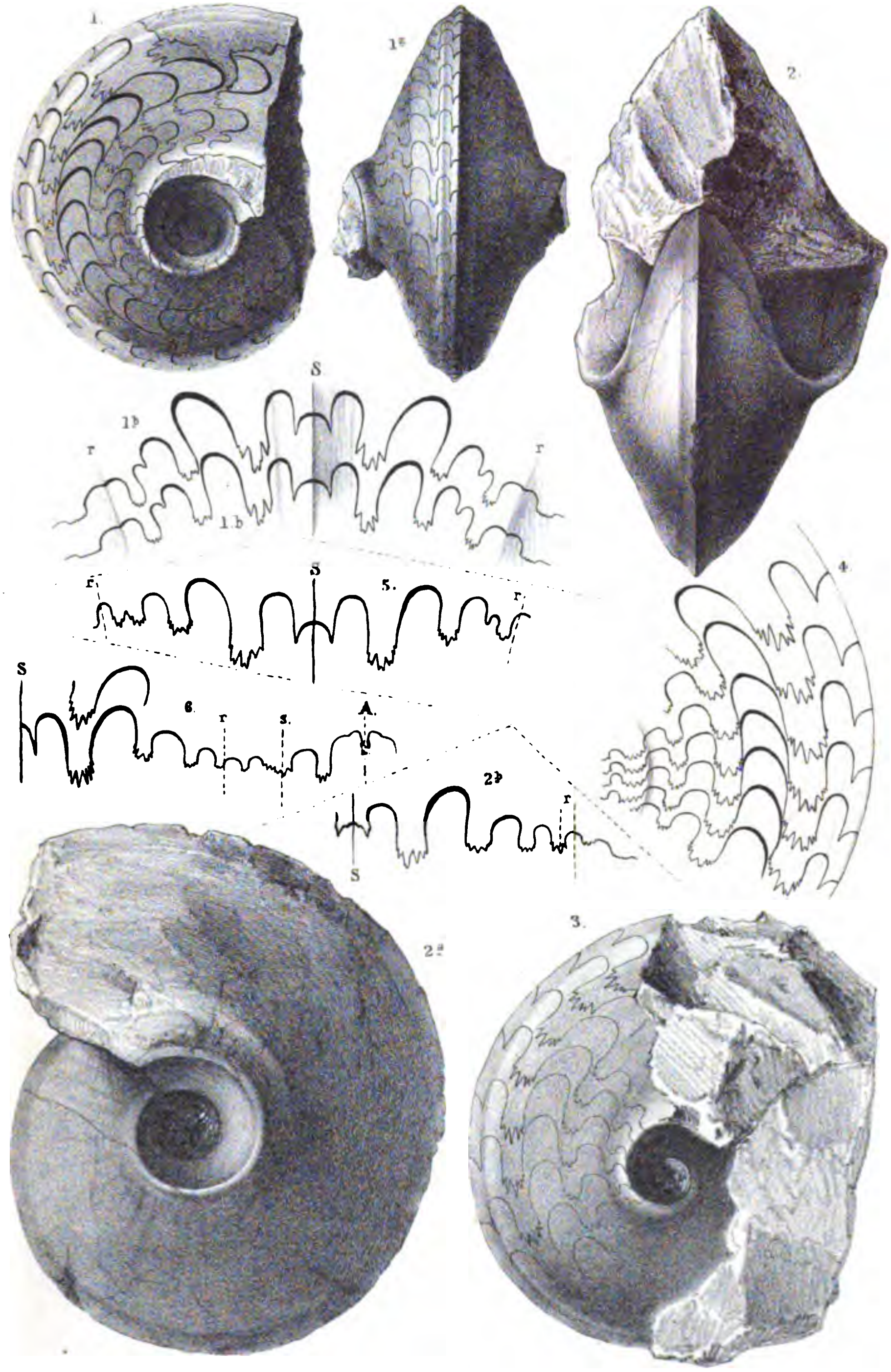

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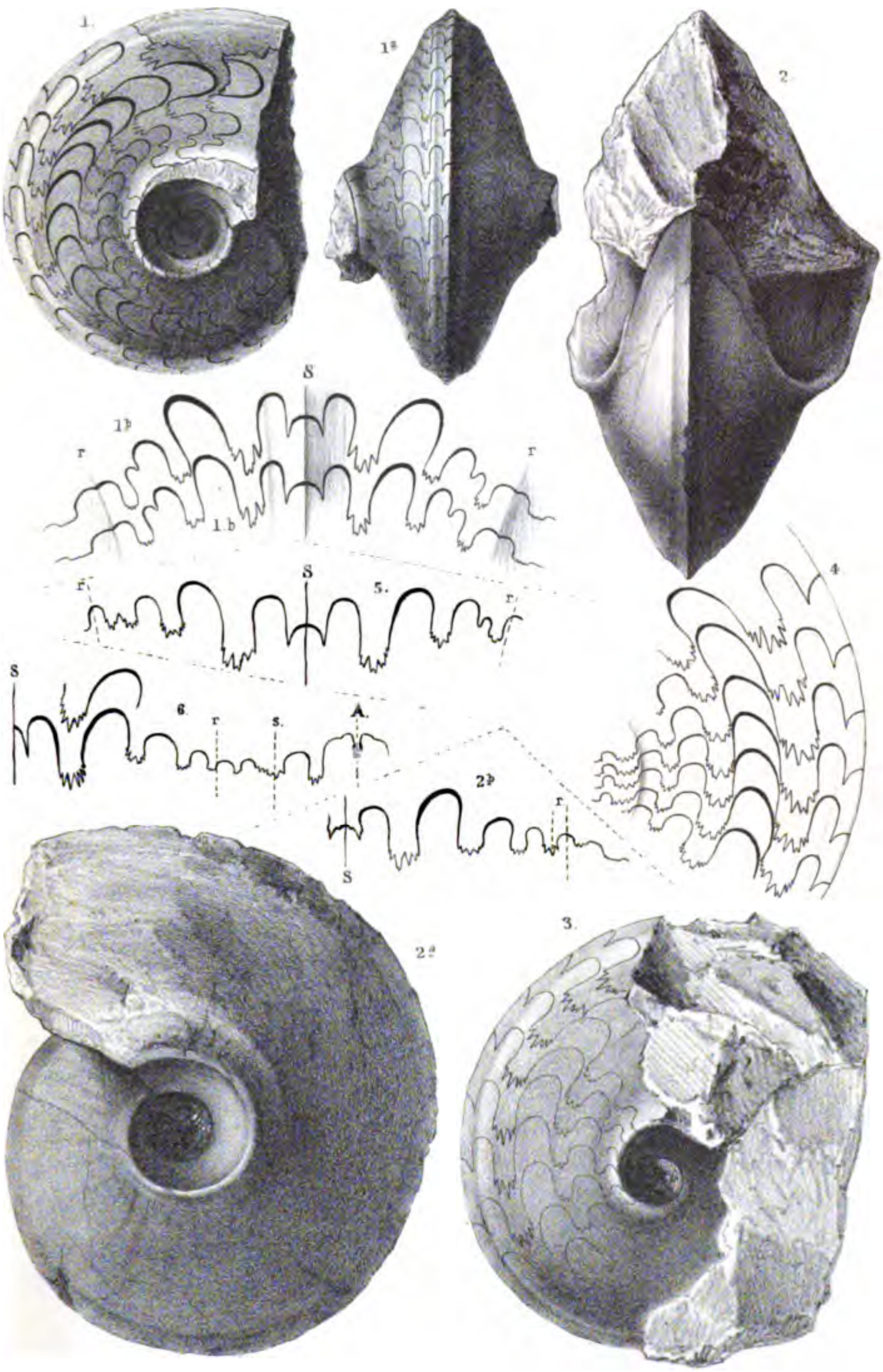

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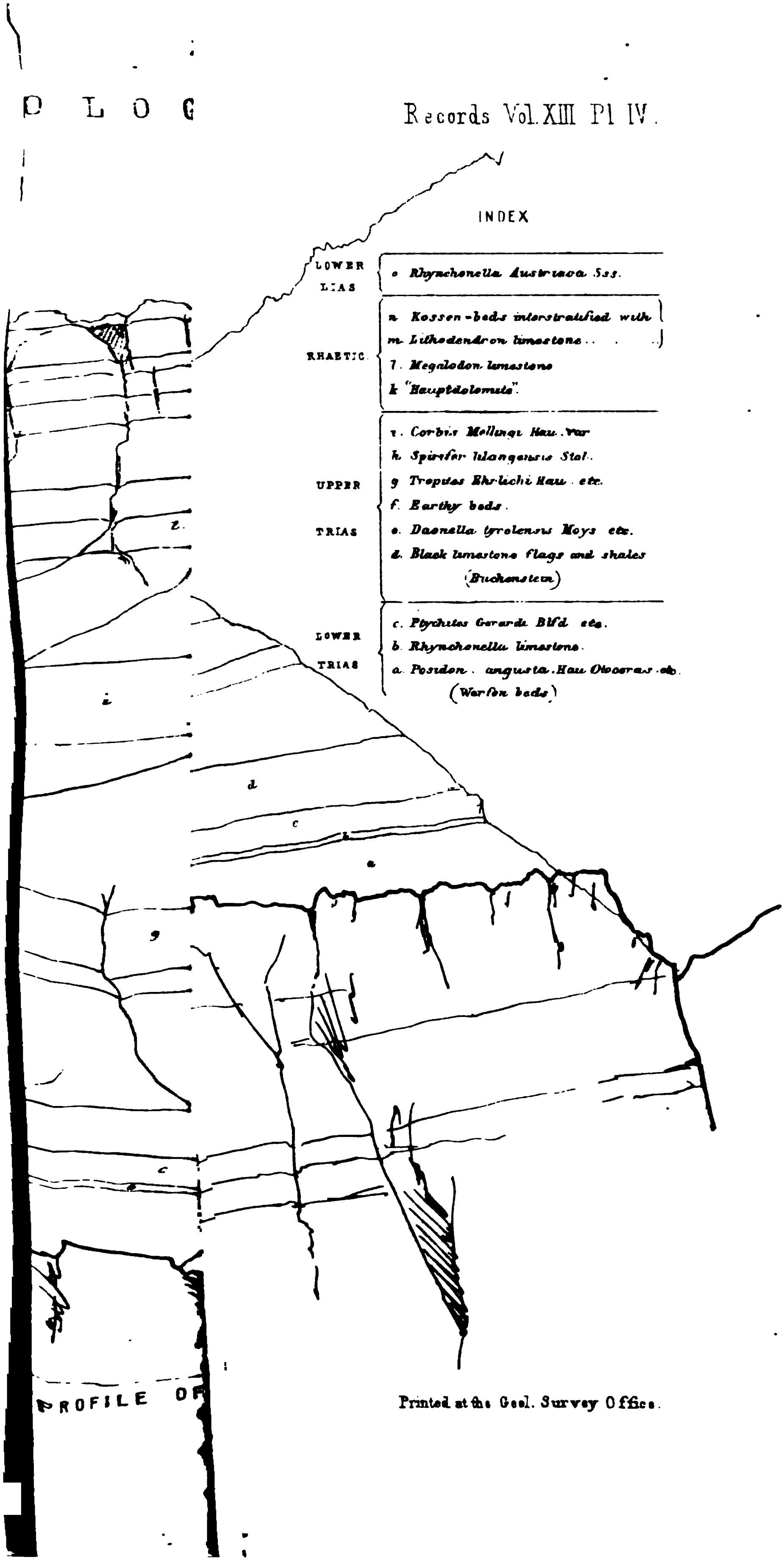

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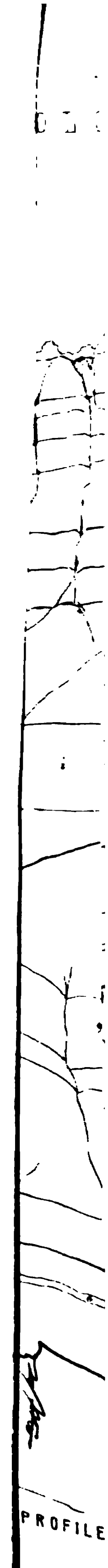

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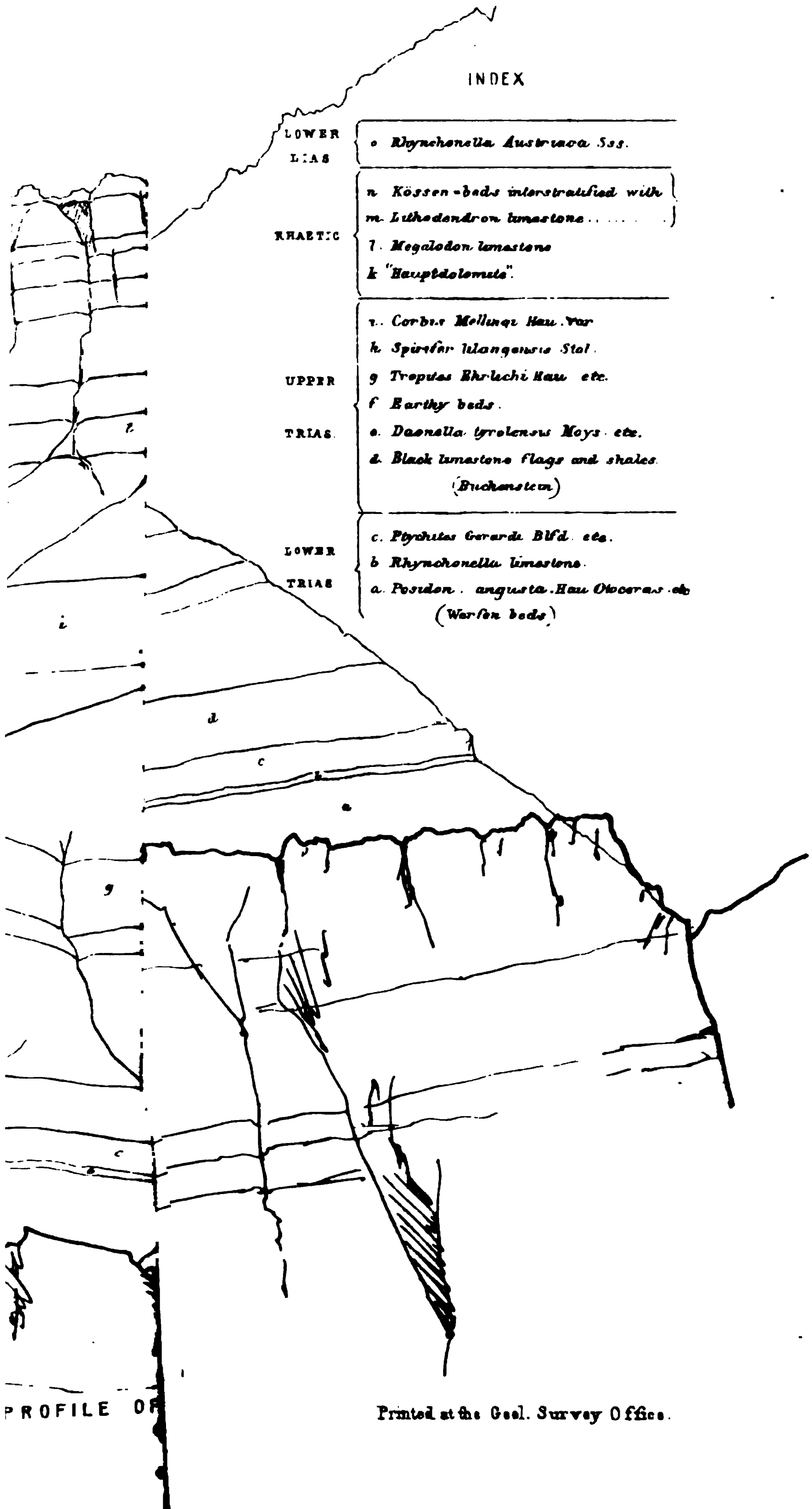

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PROFILE OF

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EXPLANATION OF PLATES.

PLATE I.

Figs. 1 to 3. NAUTILUS BRAHMANICUS, n. s.
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Fig. 5. „ var. UNDATUM, n. s.

PLATE II.

Figs. 1 to 6. OTOCERAS WOODWARDI, n. s.

PLATE III.

Figs. 1 to 7. OPHICERAS TIBETICUM, n. s.
Fig. 8. „ HIMALAYANUM, n. s.
Fig. 9. „ MEDIUM, n. s.
Fig. 10. TRACHYCERAS GIBBOSUM, n. s.

PLATE IV.

Profile of Trias and Rhætic beds of Shal-Shal in the Tibetan Himalayas. The elevation of the base of the cliff (carboniferous quartzite) is about 14,000 feet above the sea.

ON THE ARTESIAN WELLS AT PONDICHERRY, AND THE POSSIBILITY OF FINDING SUCH SOURCES OF WATER-SUPPLY AT MADRAS, *by* WILLIAM KING, B.A., *Deputy Superintendent, Geological Survey of India.*

History and progress.

Some three years ago it was announced that operations had been commenced at Pondicherry with a view to the discovery of artesian wells,—a doubtful enough experiment when the position of that city on a wide alluvial flat bordering the sea is taken into account, and that few of the ordinary physical or stratigraphical features, usually considered as giving promise of such outflows of water, are apparent at first sight. Such features do, however, occur partially; and their possible existence became gradually so impressed on the mind of Mr. Ch. Poulain, the manager of the Savana and Oopallem cotton mills, that he urged on the proprietors the advisability of making experiments, and ultimately carried out a boring with such success that water is now issuing from the tube with a hydrostatic level of nearly three feet over the surface soil and a discharge of 44 imperial gallons in the minute.

Mr. Poulain, from time to time, during the progress of this first well, read a series of papers before the Government Commission on artesian wells, in which he gave his reasons on geological and physico-geographical grounds for expecting that water-bearing strata, or sheets of water with a head, might be tapped under the Pondicherry plain, at the same time giving short notes of the progress of his work.[1] The data so recorded and other information obtained personally from this gentleman have been largely included in the present paper.

[1] See Appendix 2.

I am also much indebted to Mr. Carriol, Chief Engineer of Pondicherry, for his guidance, and for placing of all available information and assistance at my disposal in this enquiry.

The original well at the Savana filature was commenced on the 1st February 1877, and the boring (after several accidents and a removal to a short distance) having been put down to a depth of about 174 feet, the present rising sheet of water began to flow and obtained a height of nearly a foot over the soil and a discharge of nearly 20 gallons per minute on the 10th September in the same year. The flow increased to more than double this amount, and it has now been going on steadily for more than two years.

In the succeeding year a second boring was started at the Oopallem mills, and in the remarkably short period of thirty-seven days, and at the moderate expenditure of Rs. 1,500 (not accounting for apparatus and repairs), a water-bearing stratum was tapped at about 115 feet which is now discharging 99·5 gallons a minute at a height of nearly one foot over the surface, and has continued so since the 11th October 1878.

The French Government being now convinced of the occurrence of water-sheets with a 'head,' determined on developing this unforeseen source of supply. A site was selected in the Jardin d'Acclimatation; and under the administration of Mr. Carriol, the Chief Engineer, a third boring was carried out with great success, a sheet of water being struck at 261 feet which has had a discharge of 146·52 gallons a minute, at 4·85 feet over the level of the soil, since the 20th March 1879. This boring was carried out with great care, details and specimens of the strata passed through having been preserved.

It is difficult to give an idea of the very charming and inspiriting effect of this fountain so opened up in these gardens, though for a so-called fountain the height of the jet is very insignificant. The large basin is raised well over the level of the gardens for the necessary distribution of the water, while a large rose is placed over the orifice of the tube, so that the water only wells up rather violently and falls in a bubbling mass about a foot over the surface of the sheet in the basin. The mere gush of clear and brilliant water in a country where one so seldom sees water in such joyous motion, rising as it does from an unknown source, makes this fountain a most fascinating and beautiful feature, and soon tends to lead one into an enthusiastic belief in the existence of similar sources, and the possibility of opening them up, in almost any moderately extensive alluvial flat on the coast or even far inland. The Savana well is ill-placed, among the mill buildings in the deep shadow of its service well or basin, and its discharge is not so great; but the Oopallem well makes a brilliant oasis of its grass-grown mound in the otherwise rather sombre factory compound.

The supply of water from this well being sufficient for the gardens, a second boring was started under the same auspices and able administration, on about the most elevated ground in Pondicherry, in the Ville Noire, with the laudable object of distributing water over the native quarter. Here the works are on the same extensive scale, and much larger piping is used. Not, however, until a depth of 550 feet has rising water been met with; and this only comes within 35 inches of the surface, with a discharge of about 20 gallons a minute. This result

is very poor, but it is hopeful, nevertheless, the other wells having also shown similar sheets with such a low hydrostatic level.

A fifth well has also been started by Mr. Cornet, one of the proprietors of the filatures, in his own compound within the city and much nearer to the sea shore. My latest information on this boring is that a stratum of rising water had been struck at 200 feet. The water is not yet very abundant, and it is only of middling quality.

Some trials have also been recently made elsewhere in this part of India, which it is just necessary to notice here. Mr. A. de Closets, C.E., of Madras, reports as follows:—"A trial well I had bored in Madras at the then Napier Iron Works through strata of blue clay and sands alternately, reached at 30 yards an ascending water sheet of brackish water, above a stratum of a greenish kind of sandstone." This well was, I believe, abandoned on financial grounds. Again, in another boring now under operation in Madura, Mr. de Closets has been piercing alluvial strata with the hope of meeting a water sheet, but as yet without success.[1]

On the completion of the boring in the Jardin d'Acclimatation, the subject was brought to the notice of the Madras Government through an extract[2] from the *Moniteur Officiel* of the French Settlements in India, and an enquiry was then instituted as to the expediency of sinking such wells, and as to whether any suitable localities for artesian well-sinking were known in the Presidency. At this time I had only the data supplied in Mr. Carriol's report, and had not seen Pondicherry or its neighbourhood for nearly 22 years, so could only suggest the possibility of such wells being found in similarly placed alluvial flats, while I hazarded the speculation that the gush of the water might be due to the pressure of superincumbent alluvial strata. The interest attached to these wells is, however, so great that a personal inspection of them became necessary, and I was enabled to visit Pondicherry in December last, when the materials for this paper were collected.

THE SAVANA BORING.

No very detailed observations extant.

Mr. Poulain, though much interested in the strata passed through in this working and that at Oopallem, has unfortunately not given very detailed accounts of them in his papers, neither did he preserve an orderly series of specimens of the rocks. Indeed, his paramount interest and object were rather to get at the hoped-for rising sheets of water, one of which should be of a sufficient quantity and of a suitable quality for the mills which had hitherto been supplied with well-water given to depositing a coating in the boilers. The following tabular section (Table 1) has, however, been constructed from the papers he read before the Commission; it is arranged after the model of those kept at the Government borings, so as to give the details at a glance, and facilitate any correlation which may be made between the other borings.

[1] In Northern India borings for water have been made to 481 feet (Calcutta), and to 701 feet (Umballa), without success. *See* Manual of the Geology of India, p. 397.

[2] See Appendix 1.

The water here is very limpid with a faint bluish-green tinge; a very slight sulphurous odour is given off. It is reported as good to the taste, savoring an apparent metallic flavour; nitrate of silver gives a faint opaline cloud, and tannin produces no change of color. No deposit is formed on the boilers at the filature. The temperature at the orifice is 33° C. or 91·4° F. Clots and fluffy masses of rusty-green vegetable matter soon gather on the surface of the water in the service well or receiving basin.

The water

The well is situated at about 1,880 yards from the seashore, and about 250 yards from the right bank of the Edoupar, a small tributary of the northern arm of the Ariankúp or Gingee river, a short distance outside and to the south-west of Pondicherry. The nearest high ground of older rocks than the alluvial deposits is the low Red Hills plateau which commences to rise from the plain at about 2 miles to the north-west.[1]

Locality.

The tube has an internal diameter of 5·57 inches, and a total length of 172·79 feet, being made up of rivetted segments of 8·20 to 9·14 feet long.

Tubing.

Table I.—The Savana Boring.

No. of bed according to Mr. Poulain.	Arbitrary grouping of Mr. King.	Beds.	Thickness of beds in meters.	Progressive thickness in meters.	Remarks.
		Surface soil, say about	3·00	3·00	
1	A	Coarse sand, with some rounded pebbles, quartz, and sub-angular particles of (?) basalt.	1·00	4·00	1st February 1877.
2		Coarse sand, such as is employed in the making of lime.	3·40	7·40	
3	B	Black clay with the same sand and pebbles mixed in it.	0·40	7·80	As this clay was pierced, all the water disappeared from the tube.
4		Black clay more compact, scarcely any sand, pearly spangles, fragments of shells.	2·48	10·28	
5		Quartzose sand, stained with black clay, about	0·38	10·66	At 10·28, 1st rise.
6		Pure black clay, very plastic ...	5·34	16·00	At 16·00, an accident.
7		Black clay, containing a little sand ...	0·58	16·58	At 16·58, 2nd rise.
8		Pure black clay, and clay mixed with fine and coarse sand.	2·42	19·00	

[1] The height of the surface at the well over mean sea-level is 9 feet. Before the boring the water-level in the ordinary wells was 11·48 feet; but now it has risen to 8·85 feet. This increase has taken place since the surplus water of the artesian well has been allowed to flow into the tank situated in the north part of the premises.

Table I.—The Savana Boring—contd.

No. of bed according to Mr. Poulain.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
9	C	Coarse quartzose sand, brilliant and dull grains, white to yellowish-red, lower down mica spangles.	8·00	27·00	At 22·00, 1st gush.
10	D	Black clay	6·00	33·00	At 33, 2nd gush.
11	E	Grey sand of extreme fineness, fluid and even viscous.	1·00	34·00	Water lowers as boring proceeds.
12	F	Black clay, plastic, compact, with some rare black and schistose pebbles.	2·00	36·00	
13	G	Silicious sand, coarse-grained stained with a little clay.	1·00	37·00	At 36·50, a rise.
14	H	Impermeable bed of clay, less black than the previous ones: containing some grains of calcareous concretions (1 to 5 millimeters cube) and others a little larger. Sometimes a little sand, mixed or in thin seams.	8·00	45·00	
15		Same clay, with rounded pebbles, size of peas, others a little larger, black and white.	1·00	46·00	At 46, 3rd gush, but a fall below soil.
16		Coarse sand, with pebbles of quartz ...	0·50	46·50	At 46·50, water stops at 30 centimeters above soil.
17		Coarse sand, pebbles rarer, mixed with fine grey fluid sand like that at 33 meters. Lower in the bed pebbles still more rare, grains of sand very large (2-3 mm. cube) of hyaline quartz, small debris of kaolin.	0·50	47·00	
18		Coarse sand, smaller grains and rolled pebbles.	1·00	48·00	
19	I	River sand a little mixed with fine sand like sea-sand, still some fragments of white clay; then the sands alternately fine and coarse. (Here were noticed some particles of blackish calcined clay and some fragments resembling country brick, but Mr. Poulain hesitated at such recognition until some small sherds of pottery appeared; even then he admits that these may have fallen from above).	2·00	50·00	At 49·90, water stays at 50 centimeters, when all at once there is a 4th gush. Eventually water lowers rapidly.
20		Coarse sand containing pellets of black clay as large as peas; sand fine and coarse-grained, the two sands being sometimes mixed, soiled with a little black slushy clay.	1·00	51·00	

Table I.—The Savana Boring—concld.

No. of bed according to Mr. Poulain.	Arbitrary grouping of Mr. King.	Beds.	Thickness of beds in meters.	Progressive thickness in meters.	Remarks.
21	J	Debris of friable "psammite" (? ferruginous grit) tainted with some yellow ochreous clay, mixed with sand, rolled pebbles, and some lumps of hard greyish-white limestone.	1·68	52·68	At 52·68, 5th gush, 10th September 1877.
22		Coarse-grained blackish sand, then some debris of ferruginous grit of a deep brown colour, less friable than the preceding, mixed in the mass of coarse-grained white sand slightly soiled with yellow ochreous clay.			

In this table, the strata, their separate thicknesses, the progressive depths, the remarks, &c., are collated from Mr. Poulain's papers already referred to. I have myself taken the liberty of making a tentative grouping of the strata into series of permeable and impermeable beds, or an arenaceous and argillaceous grouping, thus:—

An arbitrary grouping of the beds.

Groups of beds.	Feet.	Feet.
Surface soil	9·84	9·84
A.—Coarse sands	14·43	24·27
B.—Black clays	38·04	62·31
C.—Coarse sands	26·24	88·55
D.—Black clays	19·68	108·23
E.—Grey sands	3·28	111·51
F.—Black clays	6·56	118·07
G.—Sands	3·28	121·35
H.—Clays	29·52	150·87
I.—Gravelly and pebbly beds	16·40	167·27
J.—Sands with debris of furruginous grits	5·51	172·78

The arenaceous beds were always loose and incoherent, never consolidated; the strata passed through are then clearly alluvial and recent. The tertiary red sandstones, or "Cuddalore sandstone" of the Survey nomenclature, cropping up in the low hills to the north-west, have not been touched by the boring rod, much less the cretaceous

All alluvial strata.

strata hading up still further to the west on the shores of the great Oussandan tank west of Pondicherry.

The behaviour of the water sheets.

The permeability or otherwise of the beds is very clear in this boring: no sooner is fair clay reached and pierced than the tube (filled with water from the sand above) is gradually emptied, until sand is again reached, when water again appears.[1] A sheet of water, or a seam charged with water, was, however, struck at 54·38 feet, which rose in the tube and ran over at 3·28 feet below the surface of the soil, still above sea level and also above the level in the surrounding wells; so that here was water clearly under pressure of some kind. The seam of sand and clay being, however, very thin, the boring was pushed on through the succeeding clay, until at 62·32 feet a second sheet was found to rise 11 inches over the soil, and after a short time to 17·5 inches. However, as the boring progressed, the water fell again 3·28 feet below level of soil, and then an accident occurred to the tubing which necessitated the starting of a new boring at 2 feet to one side. In the new hole similar strata were passed through, and at 72·16 feet, water at last rose to 15·60 inches above the soil.

Above first impermeable seam.

Below the 1st seam of clays.

The curious feature in the progress of these two borings only 2 feet apart, —that in about 26 feet of coarse sand without any clay the water first rose over the soil, then gradually fell to nearly 3 feet below the surface, and finally rose again to nearly 1·5 feet over the surface,—is attributed by Mr. Poulain to faultiness in his first tube, which he thinks was not quite staunch at the rivetted joinings.[2]

In the 2nd band of clays.

A third seam of permeable material (E) was again met at 108·23 feet of about 3·5 in thickness, which gave a discharge of water at 35 inches above the soil, but the boring was continued in the hope of obtaining a better flow.

At 118 feet, a 3-feet seam of sandy material only allowed of water rising to within a little more than 2 feet of the surface. It is not clear whether sufficient time was allowed here for the water to rise higher, as it ought to have done, even though retarded through a more compact condition of the sand.

Below the 2nd band of clays.

After this came 29 feet of impermeable clays (H), from below which water rose to 3 feet above the soil and then fell to 27·30 inches below that level.

The auger now passed through a more varied set of generally arenaceous beds, without any definite seams of clay or other impermeable material, yet the water rises and falls in a remarkable manner, though ultimately, at the bottom of this series, the point is reached from which the present fine flow of the Savana well rises. There are altogether some 25·35 feet of these sandy beds. After entering on this series, the water mounted slowly and stopped at 11·70 inches over the soil: afterwards it rose as high as 19·5 inches when (as graphically expresed by Mr.

[1] The fact would require that some permeable beds are quite cut off from the artesian (or any other) source, and are still unsaturated, if the word 'emptied' is to be taken literally.

[2] The explanation would suggest that the phenomenon only occurred in the first boring.

Poulain) all at once, at a stroke of the borer, the water rose rapidly and flowed out over the mouth of the tube at nearly 3·28 feet above the soil. It then fell and rose in the tube, ceased to flow, and finally lowered rapidly, at a depth of 163·57 feet. The auger still continued through what are to all appearance permeable beds, though no further rise took place until at nearly 178 feet, when there was a powerful discharge of sand. This having been gradually reduced, the water rose to a height of 11·70 inches over the soil with a discharge of 19·81 gallons a minute.

Does not imply that there are more than one sheet below last seam.

I do not think we can here, below the second band of clay, consider that more than one water sheet has been tapped. The odd behaviour of the water in its oscillations being in great measure attributable to a possible choking up of the material round the bottom of the tube as it was forced down among varied sands, in which are at times seams of clay-galls and other fragments of clayey material: while in the new movements superinduced among the water channels or passages by this suddenly opened-up vent, it is quite possible that there may have been frequent blocks. The height of the jet was, however, poor as compared with what had been attained in the earlier stages of the boring, and this and the discharge were only attained after some days. The discharge when I saw the well in December last was about 44 gallons a minute, with a hydrostatic level of about one foot over soil.

Two well defined seams or bands of clay.

For the beds exhibited by this boring: it is to be noted that there are two well-defined and thick seams of clay which act perfectly as impermeable bands, from under which water rises over the level of the soil. The lower clay seam is, however, separable into three divisions by two thin seams of sand, from each of which there was a gush of water.

THE OOPALLEM WELL.

Position.

This is situated within the compound or yard of the Oopallem filature on the Pondicherry-Cuddalore high road, and in the depression of the same small stream passing to the south-west of Pondicherry. It is within 820 yards of the sea shore, but about 650 yards to the south of the parallel of the Savana well, and about 100 yards from the left bank of the Edoupar stream.

The tubing and discharge of water.

The present discharge is 99·5 gallons a minute at a hydrostatic level of 3·28 feet. The tube has an internal diameter of 7·08 inches, and is 119 feet long.

The water.

The water is very similar in character to that of the Savana well; if anything it appeared to me to be more sparkling and to have rather a bluer tinge. The sulphurous odour is stronger. The same vegetable matter forms and floats off on the surface, perhaps rather more quickly and in better growth owing to the free exposure to air and light; the bed of the channel leading away from the basin is coated with a somewhat similar growth, and this again is covered by a very thin brown ferruginous scum. The water was distinctly tepid to the touch in the cool weather of December, and is of about the same temperature as that of the Savana; it is drunk freely by the natives.

It is to be noted that the discharge is much over that of the Savana jet. But this appears to be in proportion with the capacities of the tubes, qualified by the different depths and the more compressed strata in the deeper boring. The discharge powers of the two tubes are as 44 to 31: the actual discharges being as 99·5 to 44.

Better discharge than in the Savana well.

The following table of the strata passed through in this boring has been sent to me by Mr. Poulain:—

Table 2.—The Oopalem Boring.

No. of bed according to Mr. Poulain.	Arbitrary grouping of Mr. King.	Beds.	Thickness of beds in meters.	Progressive thickness in meters.	Remarks.
1	...	Vegetable mould	0·60	0·60	
2	A	Fine sand with clay	2·35	2·95	
3	A	Coarse sand with pebbles, and some clay near the bottom.	15·18	18·13	Rising sheet to 1 meter below surface.
4	A	Pebbles with sand, and some clay ...	0·60	18·73	
5	B	Dark clay with fine sand	2·50	21·23	
6	C	Dark and hard clay	14·47	35·70	Gushing water sheet.
7	D	Fine sand and pebbles	...	...	

The water-level in the ordinary wells is between 6·56 and 9·67 feet below surface soil, which is 6 feet above mean sea-level.

An arbitrary grouping of the beds may be put as follows:—

Groups of beds.	Feet.	Feet.
Surface soil	1·96	1·96
A.—Sands and pebbly beds with clay	59·46	61·42
B.—Dark clay with fine sand	8·20	69·62
C.—Dark and hard clays	47·46	117·08

The Boring at the Jardin d' Acclimatation.

The next well in order of date is that in the Jardin d' Acclimatation, situated between Savana and Oopallem, immediately on the south-west edge of the town, at about 1,450 yards from the seashore, 160 yards south of the parallel of the Savana well, and 170 yards from the left bank of the Edoupar.

Position.

The boring was commenced on the 30th October 1878, and the present water-bearing stratum was reached on the 13th February 1879, since which time, with the exception of a few days of gradual rise, the flow has continued at the same height and rate of discharge. The water has a temperature of 34·30 C. or 93·74 F.; it is very clear, with a faint bluish-green tinge, and has a slight chalybeate taste. A strong sulphurous odour is given off; and the usual vegetable scum is formed on the surface and floats away. It is drunk freely by the natives, and it boils vegetables perfectly.

The water and its discharge.

The following tabular section (3) is compiled from one supplied to me by Mr. Carriol and from another table given in the Proceedings of the Madras Government, Revenue Department.[1] In this table also, I have attempted a grouping of the beds according to their sandy and clayey constitution :—

Boring section.

Table 3.—The Boring in the Jardin d'Acclimatation.

No. of beds according to official table.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
		Surface soil	1·33	1·33	30th Oct. 1878.
1	...	Sand mixed with yellowish clay ...	0·75	2·08	2·80 M., waterl-evel of surrounding wells.
2	A	Clay mixed with clear grey sand ...	0·35	2·93	3·60 M., mean sea-level.
3	A	Argillaceous sand, clear grey ...	1·40	4·33	
4	B	Coarse sand, bluish, containing small pebbles.	0·30	4·63	
5	B	Sand, clear grey, fine, and very fluid ...	1·37	6·00	
6	B	Coarse sand, bluish, small pebbles ...	0·15	6·15	
7	B	Coarse sand, bright grey	0·25	6·40	
8	B	Coarse sand, bluish, containing small pebbles.	0·30	6·70	
9	B	Coarse sand, bluish, small pebbles, debris of 'charcoal' and decayed wood.	0·35	7·05	
10	B	Coarse sand, bluish, galls of black plastic clay, and decayed wood.	0·35	7·40	
11	B	Sand, very fine, bluish	0·15	7·55	
12	B	Coarse sand, blackish, mixed with black plastic clay.	0·60	8·15	At 10·24 M., first rise of water-level.
13	C	Black clay and fine sand	2·59	10·74	

[1] 7th July 1879, No. 1496. *See* Appendix 1.

Table 3.—The Boring in the Jardin d'Acclimatation—contd.

No. of beds according to official table.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
14	D	Fine sand and black slushy clay ...	0·88	11·62	
15		Coarse sand with a little clay, small pebbles.	0·40	12·02	
16	E	Fine sand, decayed wood, no clay ...	1·58	13·60	
17		Fine pure sand	2·20	15·80	
18	F	Black compact clay, with vegetable detritus.	5·40	21·20	
19		Black clay mixed with fine and medium sand.	2·90	24·10	
20		Black clay mixed with sand and pebbles	0·20	24·30	
21		Black clay mixed with medium sand ..	2·80	27·10	
22	G	Fine sand soiled with clay ...	0·20	27·30	
23		Fine grey sand	1·10	28·40	
24		Hard black clay mixed with very fine sand.	0·15	28·55	
25		Medium sand, greyish	2·15	30·70	
26	H	Sandy black clay	0·15	30·85	
27		Fine grey sand	0·55	31·40	
28		Sandy black clay	1·20	32·60	
29		Fine sand mixed with black clay ...	0·40	33·00	
30		Fine sand with clots of sandy clay ...	0·30	33·30	
31	I	Compact black clay mixed with very fine sand and some small granules of grey limestone.	6·70	40·00	
32		Plastic black clay with a few fragments of shells.	4·00	44·00	
33		Compact black clay mixed with very fine sands.	0·75	44·75	
34		Black clay mixed with medium sand ...	3·30	48·05	
35	J	Fine sand, dull, earthy and clayey ...	1·35	49·40	
36		Fine sand, less dull, earthy and clayey...	5·30	54·70	At 56·50 M., 1st gush.

Table 3.—The Boring in the Jardin d'Acclimatation—contd.

No. of beds according to official table.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
37	K	Coarse sand, clayey, containing pebbles, morsels of conglomerate and debris of ferruginous grit.	2·00	56·70	
38		Coarse sand, pure, containing small pebbles, conglomerates and ferruginous grit.	2·50	59·20	
39		Coarse sand, bluish, containing small pebbles, very white clay and ferruginous grit.	0·90	60·10	
40	L	White sandy clay	0·15	60·25	
41		White sand, with small pebbles, fragments of white clay and ferruginous grit.	5·79	66·04	
42	M	Greyish sand, small pebbles, friable white grit and quartzose agglomerate with iron pyrites.	0 56	66·60	
43		Blackish sand, friable white grits, and the pyritous quartzose agglomerate	0·80	67·40	
44		Grey sand, and the same ferruginous rock.	0·50	67·90	
45		Greyish sand, small pebbles, the pyritous agglomerate and decayed wood.	0·70	68·60	At 68·85 M., 2nd gush.
46		Grey sand, gravel, pyritous agglomerate, ferruginous grit.	0·50	69·10	
47		Grey sand, gravel, small pebbles, decayed wood, fragments of white and grey clay, and the pyritous agglomerate.	2·40	71·50	
48	N	Grey sand, very fine and pure ...	0·90	72·40	
49		Fine black-grey sand, fragments of decayed wood and vegetable detritus.	1·20	73·60	At 73·60 M., 3rd gush.
50	O	Medium sand, gravel, small pebbles, decayed wood, and pyrites.	4·20	77·80	
51		Medium greyish sand, clots of clay, gravel, small pebbles, decayed wood, and pyrites.	0·60	78·40	At 79·34 M., 4th gush, 13th Feb. 1879.
52		Medium grey sand, gravel, decayed wood, small pebbles, and pyrites.	1·12	79·52	

Clayey and sandy grouping of the beds.

My tentative grouping of the beds gives the following succession :—

	Feet.	Feet.
Superficial soil	4·33	4·33
A.—Clayey sands	9·84	14·17
B.—Alternating coarse sands	12·52	26·79
C.—Black clay and fine sand	8·82	35·61
D.- Clayey sands	4·19	39·80
E.—Sands without any clay	12·39	52·19
F.—Black clays, sometimes sandy	37·06	89·25
G.—Alternating sands and clays	11·80	101 05
H.—Alternating sandy clays and sands	8·52	109·57
I.—Thick beds of black clay	48·38	157·95
J—Fine earthy and clayey sands	21·81	179·76
K—Beds of coarse sand with some ferruginous matter	17·71	197·47
L.—White sands, clayey and conglomeratic	19·48	216·95
M.—Sands with seams of ferruginous grit	17·90	234·85
N.—Fine sands	6·88	241·73
O.—Sands, gravelly and ferruginous	19·41	261·14

Compared with the Savana grouping.

On comparing this succession with that of the Savana well, there does not appear to be very much in common at first sight, except that if we take the same depth in each, there is then the same number of groups. This, however, goes for nothing; but on looking at the groups of beds there does appear to be some faint connexion. In the Savana section, there are four distinct seams of clay, *viz.*, B, D, F, and H, while in this section there are only F and I. B, in the first, is of about the same thickness as the upper clay in the Garden section, which is, however, at a depth of 52·19 feet. A very slight dip to the eastward, which is not an unlikely supposition, would allow of these being the same bed. The clay seam, I, in the Garden well is 48·38 feet in thickness; but its upper surface is very nearly at the same depth below F as D in the Savana well is below B. There the correlation would seem to cease, for we can hardly suppose the 19·68 feet seam (D) of the Savana to have thickened out so tremendously. No other decided clay seams are found in the Garden boring, as if F and H in the Savana might also have

run to the deep. It seems more likely that D, F, and H in the Savana may have run into I in the Gardens.

Behaviour of the water sheets.

Five rising sheets of water were tapped in the Garden well. The first rise took place in C, but at a point (*vide* Table 3) which seems to indicate that the black clay and the fine sand are separate layers.

A steady rise throughout two thick bands of clays.

During the whole time the boring was going on through the groups D, E, F, G, H and I, there appears to have been a steady rise of water until the 1st gush was reached, even with the intervening (ordinarily impermeable) 37 feet of black clays of F, and the 48½ feet of thick black clays of I. It is very difficult to account for this apparent permeability of such beds, even though the boring was carried on at an average rate of more than 3 feet a day. It may have been that the partings between the separate beds of clay in each group allowed of water percolating from thinned out beds of sand: indeed if my correlation of the lower group of clay beds with the separated clay beds in the Savana section be right, then the intermediate sand beds of the latter section would thin out between the thickening clays of the F group in this boring. This closing up of the water sheets also accounts for there being no such rises of water level as those which were experienced in the Savana boring until the group H was passed.

The 1st gush takes place below the second seam of clays.

The 1st gush of water (in the Garden) took place in the group K at 185·32 feet, apparently from the freer coarse sands in the seam. On the boring being continued the water fell at last below the ground level, in the white sands of L, and so it remained until the sands of the middle of M were reached, when there was a 2nd gush, which, however, fell to 12 inches below surface in the same beds. A 3rd gush took place in the fine sands of N, but this water soon fell to level of ground. At last in the ferruginous beds of O, the 4th and permanent gush was reached.

The subsequent gushes very like those in the lower permeable seam at Savana.

Here there is little apparent correspondence between the behaviour of the springs and those of the Savana well: and certainly the intermittent action of the present water-layers is extraordinary, especially in the occurrence of the 4th gush, which, it is to be remarked, is from bed No. 52 of the Table (3), which bed does not appear to differ from 50 or 51 except in the absence of small clots of clay. It may be that these clots of clay are so matted together as to have formed a temporary impermeable layer. They are present in the bottom layers of N, from under which the 3rd gush arose, while the 1st gush came from slightly clayey beds. It seems to me that it can hardly be said that these gushes, *viz.*, the 1st, 2nd, 3rd, and 4th, are really from different water sheets; but rather that they, like the lower ones in the Savana well, are from an irregularly permeated thickness of sands and some clays which required time for free circulation to be brought about. Thus, I would suggest that both the Savana and the Garden well do after all gather their waters from the same group of sandstones.

THE BORING IN THE VILLE NOIRE.

In progress.

A fourth boring, in the Ville Noire, is still in operation, but as yet there is no definite information as to a satisfactory sheet of rising water having been tapped.

Position.

The locality has been chosen on comparatively high ground; but, from the section, I fear it is altogether too near the Red Hills to give much hope of a sufficient supply of water being found in the proper alluvial deposits, though the news of a rising sheet of water is hopeful. The boring is about 800 or 900 yards from the sea, and nearly 1,250 yards north of the parallel of the Savana well; it is also about 350 yards south of a large back-water immediately north of the city.

Tubing.

The inner diameter of the tube is 8·4 inches, but now that a depth of 550 feet has been reached, it is proposed to insert a second tube of 6·4 inches in diameter.

The boring section so far.

The following sectional table (4) is translated from a copy of the books kept at the boring, and I have in it again—though there is here no such very decided grouping of the arenaceous and clayey strata as in the southern wells—attempted a classification of the beds:—

Table 4.—The Ville Noire Boring.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in metres.	Progressive thickness in metres.	REMARKS.
		NATURAL EARTH.	0·50	0·50	
1	...	Fine pure sand, yellowish	1·00	1·50	
2	A	Medium sand, clean, reddish ...	0·40	1·90	
3	A	Fine clean sand, grey	3·50	5·40	
4	A	Fine grey earthy sand	1·70	7·10	
5	A	Fine bluish earthy sand	3·60	10·70	
6	A	Blackish sand, dirty, slimy, massive shells and crustacea, small pebbles, grey grit very hard.	3·34	14·04	Represented in bed 4 of Savana boring and perhaps by 9 and 10 in the Garden well.
7	B	Black clay, ? in laminæ, mixed with sand, shells, crustacea, small gravel, and decayed wood.	2·27	16·31	
8	B	Black plastic clay, containing decayed wood.	4·49	20·80	
9	B	Compact black clay, mixed with very fine micaceous sand, and some small calcareous granules.	4·29	25·09	

Table 4.—The Ville Noire Boring—continued.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in metres.	Progressive thickness in metres.	REMARKS.
10	B	Greyish clay, mixed with very fine sand	1·60	26·69	
11	B	Medium sand, soiled with black clay ...	1·25	27·94	
12	C	Medium sand, fine and clear grey ...	0·47	28·41	
13	C	Coarse dirty-grey sand, containing small pebbles.	4·01	32·42	
14	D	Black plastic clay	4·15	36·57	
15	D	Fine black clayey sand	0·40	36·97	
16	D	Clay marbled with reddish and bluish tints, coarse sand and pebbles.	6·92	43·89	
17	D	Pale yellow medium sand, soiled with clay.	2·00	45·89	
18	E	Dirty-grey coarse sand mixed with pebbles.	0·80	46·69	
19	E	Coarse sand soiled with clear yellowish clay, mixed with small pebbles of grit and ferruginous conglomerates.	1·60	48·29	
20	E	Coarse sand soiled with reddish clay, ferruginous pebbly grit and small pebbles.	0·80	49·09	
21	E	Blueish white plastic clay, mixed with red sand and some pebbles.	1·20	50·29	
22	E	Pale-yellow sand, gravel and pebbles ...	0·40	50·69	
23	E	Sand soiled with reddish clay and mixed with pebbles.	0·45	51·14	
24	E	Reddish yellow sand, small white and red clay-galls, grit and pebbles.	9·14	60·28	
25	E	Yellow-brown medium sand ...	1·60	61·88	
26	F	Laminæ of colored clay and pebbles ...	0·86	62·74	
27	F	Grey black clay with some gravel ...	0·29	63·03	
28	F	Plastic clay, ribboned black, yellow, red and grey.	0·30	63·33	
29	F	Plastic black clay and a little sand ...	0·20	63·53	
30	F	Coarse purple argillaceous sand, with patches of colored clay.	1·00	64·53	

Table 4.—The Ville Noire Boring—continued.

No. of bed according to official diary	Arbitrary grouping of Mr. King.	Beds.	Thickness of beds in metres.	Progressive thickness in metres.	Remarks.
31	G	Agglomeration of vegetable detritus, compact lignite and some grains of fossil resin.	0·91	65·44	
32		Reddish clayey sand, patches of colored clay, ferruginous grit and iron pyrites.	1·65	67·09	These pyritous beds seem to be represented at about the same depths in the Garden well, down to 79·52 meters.
33		Blood-red sand, ferruginous grit, pyritous and pebbly.	1·05	68·14	
34		Medium sand soiled with reddish clay ...	0·94	69·08	
35		Clear red sand and small pebbles ...	1·61	70·69	
36		Red earthy medium sand, small pebbles	2·40	73·09	
37		Clear yellow argillaceous sand, gravel and milky-white pebbles.	1·35	74·04	
38		Clear red sand, gravel and ferruginous grit.	2·43	76·87	
39		Grey black argillaceous sand, small pebbles and iron pyrites.	0·20	77·07	
40		Clear red sand, small pebbles, and patches of clay at the bottom.	5·64	82·71	
41		Coarse grey sand, with small pebbles ...	0·48	83·19	
42		Pure canary-colored sand, small white pebbles and ferruginous grit.	1·89	85·08	
43		Golden yellow argillaceous sand and small white pebbles.	2·81	87·89	
44		Yellowish argillaceous sand, colored sandy clay-galls and ferruginous grit.	1·60	89·49	
45		Dirty reddish coarse sand, pebbles, ferruginous grit, and patches of colored clay.	0·40	89·89	
46		Yellow-red sand and colored sandy clay	2·26	92·15	
47		Fine yellow-red argillaceous sand with patches or laminæ of colored clay.	2·37	94·52	
48		Dirty-yellow medium argillaceous sand, ferruginous grit and gravel.	2·06	96·58	
49		Dirty-grey sand, clots of bluish sandy clay with vegetable matter.	0·11	96·69	
50		Ashy blue plastic clay	0·15	96·84	

Table 4.—The Ville Noire Boring—continued.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in metres.	Progressive thickness in metres.	REMARKS.
51	G	Grey sand with clots of colored clay ...	0·22	97·06	
52		Fine variegated argillaceous sand ...	0·73	97·79	
53		Yellow sand with clots of variegated clay, small pebbles.	0·33	98·12	
54		Clear-red sand soiled with clay ...	1·75	99·87	
55		Yellowish sand and sandy clay, small pebbles.	1·19	101·06	
56		Coarse yellow sand, soiled with clay ...	2·53	103·59	
57		Ashy grey sand	0·81	104·40	
58	H	Ashy blue sandy clay	0·49	104·89	
59		Variegated sandy clay	0·50	105·39	
60		Grey sandy clay	3·06	108·45	
61	I	Fine yellowish argillaceous sand, gravel and ferruginous patches.	6·64	115·09	
62		Clear purple argillaceous sand ...	1·00	116·09	
63		Yellow sand soiled with clay, small pebbles and ferruginous grit.	6·89	122·98	
64		Reddish sand soiled with clay, small pebbles	0·43	123·41	
65		Yellowish sand soiled with clay ...	1·78	125·19	
66		Reddish-grey sand soiled with clay ...	1·57	126·76	
67		Yellow sand soiled with clay, slabs ('plaquettes') of ferruginous grit.	5·45	132·21	
68		Fine sand, clots of black clay mixed with vegetable detritus.	0·92	133·13	
69		Yellow sand, with slabs or patches of colored clay.	2·98	136·11	
70	J	Fine bluish-white sand with slabs of iron pyrites.	1·17	137·28	
71		Medium grey sand	1·80	139·08	
72		Medium grey-black sand with slabs* of iron pyrites.	2·08	141·16	* These slabs are composed of white quartz grains and iron pyrites; tolerably hard and compact.
73		Agglomerate of vegetable detritus mixed with very fine black sand.	0·25	141·41	

Table 4.—The Ville Noire Boring—concluded.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	Beds.	Thickness of beds in metres.	Progressive thickness in metres.	Remarks.
74	J	Coarse black argillaceous sand with iron pyrites.	0·99	142·40	
75	J	Ashy blue clay and vegetable matter ...	3·13	145·53	
76	J	Foliated ashy blue clay	0·10	145·63	
77	J	Medium grey-black sand	1·37	147·00	
78	J	Ashy blue clay, vegetable detritus, and very fine sand.	0·10	147·10	
79	J	Black sand soiled with clay, small gravel and vegetable matter.	1·00	148·10	
80	...	Dirty black-grey sand, small pebbles ...	1·96	150·06	
81	...	Yellow sand, ferruginous grit and conglomerates.	0·90	150·96	
		Grey sand soiled with clay, small pebbles.	0·60	151·56	
				164·50	Water is rising from this depth, and flowing out at 2·96 feet below the surface level, with a discharge of 13·21 gallons a minute.

Tentative grouping.

	Feet.	Feet.
Natural earth	1·64	1·64
A.—Sands	44·41	46·05
B.—Thick beds of clay	45·59	91·64
C.—Sands, with seams of pebbles	14·69	106·33
D.—Clays and clayey sands	44·18	150·51
E.—Varied beds of sand, pebbly, conglomeratic, and clayey . . .	52·44	202·95
F.—Clays and clayey sands	8·69	211·64
G.—Mixed beds of sand, clays, and gravels	130·77	342·41
H.—Sandy clays	13·28	355·69
I.—Sands, somewhat clayey and ferruginous	90·72	446·41
J.—Mixed sands, clays, and sandy or argillaceous beds, with some pyritous sands, and seams of vegetable remains	39·32	485·73
K.—Sands with pebbles and conglomerates	11·34	497·07

All these beds are still essentially loose and incoherent, with the exception of the occasional bands or slabs ("plaquettes") of ferruginous grit; and so belong to the proper alluvial deposits. It is true that they are becoming ferruginous and of yellow and red colors, and are thus somewhat like beds of the Tertiary "Cuddalore sandstones" of the Red Hills plateau to the north-westward, but they are merely the debris of these sandstones, the same kind of accumulations occurring along the edge of the rise up to the Red Hills as near the village of Mootnapallem. It may then be that the auger is nearing the Tertiary beds, but I do not think it is yet in them: certainly it was not in them when I was at Pondicherry, and then the sludge pump was bringing up stuff from 500 feet deep.

Still in alluvial deposits.

In comparing this section with those of Savana and the gardens, it would seem as though we still had the two broad series of clays, though they are hardly so sharply defined and compact. The presence of shelly and crustacean remains in the Savana and this section is perhaps the safest ground to go on for a comparison, and these are in the upper parts of the uppermost clay bands. Such remains were not noted in the garden boring, but it may be that the clay with vegetable detritus at 69 feet answers to it. However, if these clay bands are the same, it is difficult to account for no gush or even rise in the Black Town well so far.

Compared with the other borings.

If the seams of clayey and sandy layers, down to below the second band of clay, be the same, then some explanation may be given for the non-rise of water in this boring. From the Savana well to the Ville Noire section, there is a very slight dip to the northward of the impermeable bands, along which sufficient friction may be developed to stop a rise. Again, the Ville Noire clay seams dip to the garden well at a quicker angle: so that really, though the supposed head of water would allow of all the seams being evenly filled up with water, it may be that the flow to the dip is stronger than the tendency to rise in the Black Town well.

An attempt to explain non-rise of water.

This would open up the question, whether the discharge at the Savana and in the gardens may not be sufficient to operate against the tendency to rise in the Ville Noire; and again, whether the water-supply of these wells is so great as the implied storage from the two rivers and the wide alluvial basin in the neighbourhood of Pondicherry.

Doubt as to an unlimited supply of water in the Pondicherry seams.

SUMMARY OF DATA AND CONCLUSIONS.

The data thus obtained regarding the flow of water, the water itself, the strata passed through, and the position of the wells, and the conclusions and conjectures which I have been able to draw from them, may now be summarized as follows:—

There has been a continuous discharge from each of the wells for one year at least, and one of them has been flowing for two years and six months. The hydrostatic level gradually increased, within a short time, up to a certain point and has remained so

The flow and gush of water steady.

without any sensible diminution up to the present time. The discharge also gradually obtained its present rate, and there has been no sensible decrease.

The wells, artesian.

The gush must then be due to hydrostatic pressure, and the wells must be considered, as was always contended for by Mr. Poulain, as properly artesian.

The water the same in all the wells.

The water is generally of the same quality and constitution in each well; if anything, that of the Oopallem well is brighter, clearer, and of a bluer tinge. It contains the same vegetable germs.

The bands of permeable and impermeable strata appear to be the same in all.

The borings are all in the alluvial deposits; but one of them (that of the Ville Noire) is near the bottom of these. There is a certain relation between the beds pierced in each bore-hole, which leads to the conclusion that groups of them are continuous over the area tapped. The upper clay seam or band certainly appears to be the same in all; it is very nearly the same thickness throughout, and it is the estuarine set of beds usually found at such a depth on the Coromandel. The second clay seam is not so clearly represented in each section; but there are strong points of similarity. A peculiar pyritous set of beds associated with seams of vegetable debris occurs once in the garden well and twice in the boring at the Ville Noire, and that in the former appears to correspond to the upper one in the latter.

The strata have a slight dip to the eastward.

The Savana, Garden, and Oopallem wells are nearly in a line ranging, from the first, in an east-south-east line for about 470 yards to the garden, and then south-east-by-south for about 770 yards to Oopallem, that is, tolerably in the line of dip which the strata might be supposed to have in this locality.

In the Savana and Garden wells, the upper clay seam has a dip of 2° to 3° to the eastward, and from this line it rises slightly to the Ville Noire section. Very nearly at the same depth below the upper clay band comes the second seam, but it has a flatter lie; indeed, it would appear to be almost horizontal in the triangular area formed by the Savana, Garden, and Ville Noire points.

Conjecture as to the "head" of the 1st rise of water; and the Oopallem sheet.

A rise of water took place in the Gardens from the sandy beds above the upper clay seam, which seems to indicate that its head may be at no great distance from Pondicherry.

Water gushed in this and the Savana borings from the permeable band below the upper clays; but the flow did not give promise of permanency. I think, however, the Oopallem water rises from the arenaceous band between the two main clay seams.

In both the Savana and Garden wells the jet now obtained began at different levels in the arenaceous strata below the second clay seam. It is questionable whether these rise from separate sheets.

Conjectures as to the lie of the strata.

If the upper clay seam preserves its dip and is continued to the westward, it might crop up to the surface at two miles back, or in the bed of the Ariancup or Gingee river at only a few miles west of Pondicherry. It is also possible that the lower seam might crop up within six miles west of the new vents. On this it is conjecturable that the

Oopallcm well may draw its waters from a source within six miles of Pondicherry.

THE PONDICHERRY-CUDDALORE ALLUVIAL BASIN.

The wells are then all in the alluvial deposits; indeed, as will be seen later on, it was not to be expected that any but very deep borings could reach the older rocks, which by their lie might be presumed to hold water with a head; it therefore becomes necessary to enquire into the condition of these deposits in this region which give this hydrostatic level to their waters at the sea-board.

Mr. Poulain's views on the source and head of water.

Mr. Poulain is, I think, firmly convinced that the head of water is gained on the distant western edge of the alluvial plain behind Pondicherry from the Pennár and Gingee rivers, his arguments being fully given in his series of papers[1] read before the Artesian Wells Commission. The facts relied on are the hydrostatic level, much diminished, however, by friction in the distance traversed by the water; the immediate growth in it, after discharge, of vegetable matter similar to that seen in the river mentioned; and an apparent rise of the hydrostatic level in accordance with an observed rise in the rivers. The endurance of the flow is again very suggestive of a constant and large supply of water, such, indeed, as we might think could only be kept up by two rivers of this size and a large basin for its reception and storage.

Remarks on these.

The correspondence between the rise of the rivers and any rise in the jets requires more and very careful observation, and Mr. Poulain expressed himself to me as not being very sure on this point. The vegetable matter is certainly similar to that seen floating along the river channels, but the same growth may be observed on the surface of most wells and certainly in the channels leading from them. Little can be made out of the quality of the water, for it must have undergone many changes in its passage through the different beds, even if it percolated only along one series. I should certainly never take it to be water from the higher levels of the Gingee or Pennár, for, outside of the alluvial area these waters have travelled over gneiss which is frequently weathered, and over soda soils. To all appearance, it might have come from the great tank some 7 or 8 miles to the west of Pondicherry.

However, there is the hydrostatic level which requires a head, and some distance is required for that in a gently sloping plain. For the constant and large supply of water, so far, the difficulty is not great, the whole amount discharged from the three wells in the year being only about 160,065,975 gallons, or say 737,000 cubic yards.

The alluvial basin.

The Pondicherry-Cuddalore alluvial plain or bay may be said to have its head at the village of Allabadi on the Pennár at about 27 miles west of the sea shore. From this point, the bay widens out to the east-north-east and east-south-east, the one edge going away, without much indentation, towards Cuddalore, which town is situated on the southern seaward arm or horn of the plain, while the other bends round in two loops up

[1] Travaux des Commissions Locales, Pondicherry, 1877.

the Gingee valley before it trends round again with a south-east curve towards Pondicherry. In this way the plain widens out considerably for a time until it has a breadth of some 24 miles, and then it closes in towards the sea-coast to a breadth of some 12 miles between the low plateau headlands of the Red Hills of Pondicherry on the north and Capper Hill near Cuddalore to the south, after which it again widens out to the sea beach by the two arms or horns already mentioned, only the northern horn is flanked to the sea by the Red Hills, which drop down in low cliffs to the belt of sea sands.

Its area, &c.

The area of the plain may be roughly stated at 500 square miles, and the boundary or edge receptive of waters from the adjacent rising ground may be taken as 150 miles long. The drainage supply of this basin is, however, tremendously increased by the two large rivers flowing into it.

Surface inclinations.

An estimate of the surface inclinations may be made from a calculation by Mr. Carriol, who states that the village of Villapuram ($23\frac{1}{2}$ miles due west of Pondicherry) is 154·84 feet above mean sea-level, which would give a rise of $6\frac{1}{2}$ feet in the mile. Allabadi at the head of the plain is about 12 miles further west, and at the same rise would be 232 feet above the sea; but as Villapuram is at the end of a spur of rather elevated ground between the two rivers, there can hardly be such a difference between it and the bed of the Pennár below the above village. It will be safer to take the level of the river bed as about the same as that of Villapuram: so that from its debouchment on the plain to the coast there is a fall of at least 4·36 feet in the mile.

Form of the basin and the lie of its alluvial deposits.

The basin in which the alluvial deposits of the plains are laid down appears to slope gradually from its western edges, but to deepen more suddenly on its north and south edges, though it again has a shelving edge on the seaward side of the Pondicherry Red Hills. The borings themselves do not show very much as to the thickness of the deposits, though that in the Ville Noire makes it 542 feet, comparatively close (about $1\frac{1}{2}$ miles) to the Red Hills. As far, too, as these borings go, there appears to be a tolerably flat lie of the beds, or at any rate a very low dip of between 2° and 3° to the eastward.

The geology of the floor.

The floor of the basin is a wide hollow worn in the gneiss or bottom rock of the country, its northern and southern edges being of the overlying cretaceous and tertiary strata which were once continuous over what is now the hollow. The latter formations are dipping at low angles to the eastward, and form a slightly elevated country to the westward of Pondicherry and Cuddalore; so that a traverse from either of these places passes from the alluvium to the rising plateau hills of red tertiary sandstones and conglomerates (Cuddalore sandstones) of the Red Hills, across these and down to a lowlying belt of cretaceous rocks, and then on to the further rising grounds of the crystalline or floor rocks. At the Pondicherry side, this order of outcrop is not quite so regular; here the red sandstones have not been so completely denuded to the westward, and thus a patch (the well-known fossil wood beds) of these still remains at Trivucari lapping over the cretaceous beds on to the gneiss.

The stratigraphy of the formations older than the alluvium is thus so far favorable for artesian borings, were the latter carried to a sufficient depth; but it is just this depth and the probability of having to pass through the hard and coarse grits and conglomerates of the Cuddalore sandstones which would make them impracticable.

Considerations on other localities suitable for artesian wells.

The wells are then sunk in the northerly seaward corner of an extensive coastal alluvial plain or basin, into which flow two large rivers whose waters may be relied on in great measure for keeping the permeable strata well filled, and which spreads back far enough from the coast for its surface inclination to give a head to these waters. Such is the broad and patent condition of affairs here; hence in enquiring as to the suitability of other parts of the Coromandel (or even further inland) for artesian borings, the most evident requirement is that they should have all the capabilities of the Pondicherry-Cuddalore basin to ensure success.

Doubts as to the necessity for so large a basin.

Nevertheless, there are certain points (some of them already hinted at) which make me doubt whether the size of this basin or the large supply of water received into it, or even the head attainable at the entrance of the rivers on the plain, are really necessary for the discharge and hydrostatic level attained. It is a question with me whether, for instance, the same hydrostatic level could not be attained with a much lower head, at a lesser distance from the vents; there being no doubt that the supply of water, obtained so far, is not beyond what the Ariancup river could give to absorbent strata only a few miles from its mouth. The irregular oscillations of the water rise in the southern bore holes; and the failure of a rise in the Ville Noire boring through all the strata which appear to correspond to those of the former wells and for such a depth seem also to point to a head not far distant, and only a moderate supply of water. I find it hard too to believe in the implied great extension of the impervious seams or bands met within the borings; the few outcrops of alluvial strata which I have seen in high river banks having generally given indications of ultimate thinning out within comparatively short distances, for the most part up, but very often down, the river's course. It is again difficult for one to conceive that the borings, so very shallow in such a wide plain, south of the town, have run down anywhere near strata holding water absorbed in the higher reaches of the rivers within the edge of the basin.

Other localities of alluvial deposits.

The town of Cuddalore, situated as it is at the southern seaward corner of the same basin, is, on the face of it, the most obvious place to try first. But the city of Madras is for many reasons the more important site. At the same time, there would appear to be even better sites than Cuddalore, on the deltas of the Cauvery, Pennér, Kistna, and Godavari.

Madras at first sight not so favorably situated.

Madras, though on the edge of a remarkably long belt of coastal alluvium, is directly in front of only a small alluvial bay or plain, very much smaller than that of the French settlement: so that if it were necessary to go entirely on the charac-

ters of the latter area, there would not be much probability of success here. Its alluvial deposits are, however, not confined to this bay, but are connected, to the north-west, with the great flat of the Cortelliar and Narnaveram river basins, the permeable beds of which may trend down in this direction.

Its proper alluvial bay small, but still possibly able to supply water with a head.

This western plain is flanked to the north and south respectively by the Red Hills and by the St. Thomas' Mount range of high ground, whence it spreads outwards and seawards, joining the Cortelliar alluvium on the one side and stretching down the coast to Covelong on the other. It extends to the westward by a long arm, at the western end of which it is again connected with the Cortelliar alluviums by a narrow neck across the south-westerly extension of the Red Hills plateau; and it sends another good arm to the south-west past the Palaveram hills. Its extreme length to the western neck is about 20 miles, the breadth between the two low headlands being about 7½ miles. The receptive edge is not more than 80 miles in length, and the area, including the stretch to the coast, is at a rough calculation about 175 square miles. It is only fed by the Triplicane (also called the Madras river and the Cooum) and the Saidapet (otherwise the Adyar) rivers, which have, however, only small drainage areas. There is a possibility, however, that a fair supply of water may be drawn in at the western neck by the narrow channel there connecting the Cortelliar alluviums with those of the Triplicane river. In fact, unless there is a supply of this kind at that point, no head of water can, I think, be reckoned on until within 8 miles of Madras, when waters would have a sufficient receptive edge and length of river bed for their collection.

There is every reason to suppose that the uppermost of the two clay bands at Pondicherry may even be found in the Madras plain, the same kind of shelly deposit having been met with in the few shallow borings which have from time to time been made, while the extent of this plain compared with the size of the streams flowing into it seems to indicate a wide-spread or westward extension of estuarine beds.

I have already expressed my opinion that the water of the Oopallem well is from the permeable band under the upper clay seam of the Pondicherry plain, and there is just a possibility that this permeable seam may crop up in the Gingee or Ariancup river a few miles west of the town. This is a bare possibility only, which, however, does not practically affect the Pondicherry supply; but it is the only supposition which gives promise of any rise from small basins like that of Madras, and it may be that the head gainable at 6 or 8 miles from the coast would be sufficient for a rise. The quantity of water is, I believe, attainable in the Madras bay, within 8 miles of the town.

The proximity of the Cortelliar and Narnaveram plains.

Fortunately, however, as I think, for Madras, it is situated on the southern arm of the Cortelliar and Narnaveram plains, and in these there are, to all appearance, all the necessary requirements as to head of water gained by distance on a gentle rise, combined with a very large reception edge. The Cortelliar plain is also joined in a remarkable way with that of the Palar river at a point above where the latter has a clear channel through the gneiss, and it is not at all improbable

that there is at this high level barrier a take-off of the Palar waters into the Cortelliar basin. There is, of course, first the chance that the permeable beds of the Cortelliar may not stretch downward to and under Madras; but this is hardly to be expected, after what is known of the tailing-up of the water-bearing strata of Pondicherry, even though that town be on the north arm of its plain, and that there is a well-known tendency of the rivers on the eastern coast to trend up to the northwards in their alluvial basins.

Obstacles in the way of an irregular bottom to be expected.

There are, on the other hand, dangers that borings may meet with obstructions or may not be able to run deep enough at Madras itself, though it is possible these may not be encountered at a short distance west or north of the city: indeed, the chances of reaching the Cortelliar beds would be increased the further north the trials were made. The line of the Palaveram and Mount ridges of gneiss may extend for some distance underneath the alluviums towards the town; in any case the mere rising ground itself has a tendency to shelve under the Adyar, and this floor would very likely come within the range of shallow borings. Again, it appears[1] that a boring was many years ago made at the then Inland Customs House at Madras, three-quarters of a mile from the sea, to the depth of 55 feet, which reached the crystalline rocks. The obstacle may indeed have been a boulder of those rocks, such being sometimes met with in the alluvium, but the likelihood is that it was a sub-alluvial extension of the Mount ridges.

The section[2] in this boring was as follows:—

	Ft.	Ins.
Sand and clay	8	0
Light-coloured sand and clay	1	0
Stiff clay	3	6
River sand	5	6
Black clay mixed with sand and shales	20	0
Blue clay with sand and lime and pieces of ironstone	12	6
Granite and quartz rubble	0	6
Clay and gravel mixed with broken granite, quartz, mica, &c.	9	0
TOTAL	55	0

[1] *See* Manual of the Geology of India, pt. I, p. 423.
[2] Newbold: Journ. Royal As. Soc., pt. VIII, p. 248.

APPENDIX I.

No. 1426, dated 7th July 1879.

Proceedings of the Government of Madras, Revenue Department.

TRANSLATION.

Extract from the "Moniteur Officiel" of the French Settlements in India, dated Friday, the 4th April 1879.

ARTESIAN WELLS.

In publishing the report of the Colonial Engineer, President of the Commission on Artesian Wells, on the boring operations carried on in the Jardin d'Acclimatation, the Administration desires to draw attention to the important results obtained, and to the hopes which this successful experiment should give rise to as regards the interests of agriculture. It is, in effect, advisable that private industry taking advantage of the experience acquired, should apply the same processes to borings to be made in other parts of the territory.

The Administration proposes, moreover, to utilize the apparatus which the Colonial Council first thought of getting out from France, on works for which sanction will be requested from the Elective Assemblies, with the view of extending these boring operations which are more productive and useful in this Colony than anywhere else.

ENCLOSURE No. 1.

Report on the Operations of Boring an Artesian Well in the Jardin d'Acclimatation at Pondicherry, dated Pondicherry, 24th March 1879.

Mons. l'Ordonnateur.—Conformably to your communication, No. 333 of the 15th February last, I have the honor to forward a full report on the operations connected with boring an artesian well in the Jardin d'Acclimatation at Pondicherry.

In order that the report may be complete, I have deemed it necessary to go back to the formation of the Commission appointed by order of the 23rd February 1877, and to the commencement of the operations which decided the Administration to encourage and popularise an advance in the means of the Colony, and of which the results ought to prove most beneficial to agriculture and rural requirements.

Consequent on the success achieved in sinking an artesian well by the aid of the "Savana" Machine as carried out by Mr. Charles Poulain, Manager of Poulain's Spinning Factory, a Commission appointed by an order of His Excellency the Governor, dated 23rd February 1877, under the presidency of the Colonial Engineer and Chef du Service of Roads and Bridges, proposed to the Administration on the 20th of June of the same year that a complete set of machinery for boring should be procured. This Commission intimated their preference for that of Messrs. Dégousée and Lippman to any other, and suggested that a sum of 1,200 francs should be placed at the disposal of Mr. Charles Poulain (who found himself without funds) in order that he might carry on his work.

The machinery arrived in the Colony on the 4th September 1878, and the Commission, after visiting the Jardin d'Acclimatation, were unanimously of opinion that the well ought to be sunk in the centre of the basin in that garden, that situation being the one which offered the greatest facility for irrigating so large an extent of ground presuming the probable success of the undertaking.

After fitting and erecting the crane, the works were carried on under the supervision and with the assistance of the Department of Roads and Bridges. First of all, a small well 1·80 metre deep was dug in the centre of the basin, at the bottom of which boring was begun on the 30th October 1878, commencing with tubes of a diameter of ·26 of a metre. The work which on this date has reached 79m. 52c. in depth has passed through the following series of geological strata:—

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry.

Number of Strata.	Dates.	Geological Strata.	Thicknesses of Strata.	Progressive Depths.	Remarks.
			M.	M.	
0	30th October 1878	Natural earth	1·33	1·33	
1	30th „ „	Sand mixed with yellowish clay	0·75	2·08	(m. 2·80) water-level of surrounding wells.
2	30th „ „	Clay mixed with clear gray sand	0·85	2·93	(3·60) mean sea-level.
3	31st October and 2nd Nov. 1878.	Clear gray sandy clay ...	1·40	4·33	
4	4th November 1878	Coarse bluish sand mixed with small gravel.	0·30	4·63	
5	5th, 6th, 7th, 8th, 9th, and 11th November 1878.	Fine, clear gray sand, very fluid	1·37	6·00	
6	12th November 1878	Bluish gray sand mixed with small gravel.	0·15	6·15	
7	12th and 13th Nov. 1878.	Coarse clear gray sand ...	0·25	6·40	
8	13th November 1878	Coarse bluish sand mixed with small gravel.	0·30	6·70	
9	13th „ „	Coarse bluish sand, small gravel, fragments of charcoal and decayed wood.	0·35	7·05	
10	14th „ „	Coarse bluish sand, lumps of plastic black clay and decayed wood.	0·35	7·40	
11	14th „ „	Very fine bluish sand ...	0·15	7·55	
12	14th „ „	Coarse blackish sand mixed with black clay.	0·60	8·15	
13	15th „ „	Black clay and fine sand ...	2·69	10·74	(10·24) first rise of water-level.
14	15th „ „	Fine sand and diluted black clay	0·88	11·62	
15	15th, 16th Nov. 1878	Coarse sand with a little clay and small gravel.	0·40	12·02	

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry—contd.

Number of Strata.	Dates.	Geological Strata.	Thicknesses of Strata.	Progressive Depths.	Remarks.
			M.	M.	
16	16th, 18th „ „	Fine sand and decayed wood ...	1·58	13·60	
17	18th, 19th, 20th, and 21st Nov. 1878.	Fine pure sand	2·20	15·80	
18	21st, 22nd, 23rd November 1878.	Close black clay with vegetable detritus.	5·40	21·20	
19	23rd, 25th, and 26th November 1878.	Black clay mixed with fine and moderate sized sand.	2·90	24·10	
20	26th November 1878	Black clay mixed with sand and small gravel.	0·20	24·30	
21	26th and 27th Nov. 1878.	Black clay mixed with moderate sized sand.	2·80	27·10	
22	27th November 1878	Fine sand stained with clay ...	0·20	27·30	
23	27th and 28th Nov. 1878.	Fine grayish sand	1·10	28·40	
24	28th November 1878	Hard black clay mixed with very fine sand.	0·15	28·55	
25	28th and 29th Nov. 1878.	Moderate sized grayish sand ...	2·15	30·70	
26	29th November 1878	Black sandy clay	0·15	30·85	
27	29th „ „	Fine gray sand	0·55	31·40	
28	30th „ „	Black sandy clay	1·20	32·60	
29	30th „ „	Fine sand mixed with clay ...	0·40	33·00	
30	30th „ „	Fine sand and lumps of sandy clay	0·30	33·30	
31	30th November, 1st, 2nd, 3rd, 4th Dec. 1878.	Close black clay mixed with very fine sand and quantities of gray limestone.	6·70	40·00	
32	5th, 6th, 7th, 9th, 10th, and 11th Dec. 1878.	Black plastic clay with a few fragments of shells. ...	4·00	44·00	
33	11th December 1878	Compact black clay mixed with fine sand.	0·75	44·75	
34	11th, 12th, 13th Dec. 1878.	Black clay mixed with moderate sized sand.	3·30	48·05	
35	13th and 14th Dec. 1878.	Fine sand and dark earthy clay	1·35	49·40	

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry—contd.

Number of Strata.	Dates.	Geological Strata.	Thicknesses of Strata.	Progressive Depths.	REMARKS.
			M.	M.	
36	14th, 16th, 17th, 18th Dec. 1878.	Fine sand, earthy clay less dark	5·30	54·70	
37	18th, 19th, 20th Dec. 1878.	Coarse clayey sand mixed with small gravel, conglomerates and ferruginous sandstones.	2·00	56·70	(56·50) 1st gushing out of water. The interval of time between the 21st December 1878 and 2nd January 1879 was employed in clearing away the sand in order to obtain a larger discharge.
38	20th, 21st Dec. 1878, and 2nd January 1879.	Coarse pure sand (same materials as above).	2·50	59·20	
39	3rd January 1879...	Coarse whitish sand mixed with small gravel, very white clay and ferruginous sandstones.	0·90	60·10	
40	3rd, 4th January 1879.	White sandy clay ...	0·15	60·25	
41	4th, 6th, 7th, 8th January 1879.	White sand mixed with small gravel, ferruginous sandstones, fragments of white clay.	5·79	66·04	
42	9th January 1879.	Grayish sand, small gravel, white friable sandstone, quartzo-metallic conglomerates and ferruginous sandstones.	0·56	66·60	
43	10th " "	Blackish sand (same materials without the gravel).	0·80	67·40	
44	10th " "	Coarse sand and quartzo-metallic conglomerates.	0·50	67·90	
45	11th " "	Grayish sand, small gravel, metallic conglomerates and decayed wood.	0·70	68·60	(68·85) 2nd gush.
46	11th, 13th, 14th, 15th January 1879.	Gray sand, grits and metallic conglomerates.	0·50	69·10	
47	15th, 16th, 17th, 18th, 20th, 21st, 22nd, 23rd, 24th, 25th, 27th, and 28th January 1879.	Coarse sand, sand, small gravel, decayed wood, fragments of white and gray clay and metallic conglomerates.	2·40	71·50	
48	29th, 30th, 31st January 1879.	Very fine and pure gray sand...	0·90	72·40	
49	1st, 3rd February 1879.	Fine black and gray sand, fragments of clay, decayed wood and vegetable detritus.	1·20	73·60	(73·60) 3rd gush.

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry—concld.

Number of Strata.	Dates.	Geological Strata.	Thicknesses of Strata.	Progressive Depths.	REMARKS.
			M.	M.	
50	3rd, 4th, 5th, 6th, and 7th February 1879.	A moderate sized sand, grits, small gravel, decayed wood and iron ore.	4·20	77·80	
51	7th, 8th, 10th, 11th, and 12th February 1879.	Moderately gray sand, lumps of clay, grits, small gravel, decayed wood and iron ore.	0·60	78·40	(79·34) 4th gush.
52	12th, 13th, 14th, and 15th February 1879.	Moderately gray sand, grits, decayed wood, small gravel and iron ore.	1·12	79·52	

Drawn up by the Colonial Engineer, Chef du Service of Roads and Bridges.

A. CARRIOL,
Pondicherry.

The 24th March 1879.

On the 15th November, after thirteen days of work, a rise of water-level was found at a depth of 10·74 metres. The water-level, which was originally 2·80 metres below the level of the soil, rose to 1·27 metres. The water was of the same character as that of surrounding wells, the water-level of which remained stationary at 2·80 metres.

These first 10·74 metres (which gave a mean depth sunk of ·82 of a metre per diem of ten hours of actual work) consisted of alternate layers of ordinary gravel mixed with clay, fine and very fluid sand, lumps of black plastic clay, bits of decayed wood, and of coarse blackish sand mixed with black clay, and were bored either by a rotating auger (tarière), or by means of a "soupape à boulet." This last implement produced the best results, especially in quicksand, during the whole course of operations.

From the 15th November to the 20th December, boring continued without interruption; the level of the rising water rose higher and higher; from 1·27 metres, which it had when first met with, it rose till it was not more than ·95 of a metre below the surface of the ground on the 18th. It remained at this level till the 20th December, on which date at a depth of 56·50 metres, a gush of water was encountered.

This outflow showed itself on the night of the 19th. The temperature of the water was 31° centigrade, and its hydrostatic level rose ·55 of a metre above the level of the ground. During the boring, the water rose and fell intermittently, varying between ·40 and ·44 of a metre. This was the result of the continuance of the operations. On the 21st December, the hydrostatic level rose to ·99 of a metre and gave a discharge of 140 litres a minute. Work was carried on at this time in a stratum of coarse gravel mixed with clay and small gravel. The water-level remained stationary for some time; the discharge increased considerably, rising from 140 to 224 litres between the 21st and the 24th December. The temperature of the water was 34°, and on analysis by Mons. Cazalis, 1st Class Chemist of Marine, showed

the following composition, as embodied in the Proceedings of the Commission of the 28th December 1878:—

Sulphate of lime	0,1050	
Carbonate of lime Silica Magnesia Iron (traces of)	0,0210	Substances precipitated by soap and water.
Chloride of soda	0,1800	
TOTAL	0,3060	

These proportions not constituting a perfectly drinkable water, though very useful for watering the garden, the Commission determined to carry on operations to a greater depth. The tubing was accordingly continued with pipes of the same diameter as at the beginning. From the 30th December, under the impetus given to the works, the hydrostatic level commenced to fall, and in consequence the discharge of water underwent the same diminution. From 1·28 metres which it had attained, there was not more than 1·005 of a metre on the 31st December, ·83 on the 4th January 1879, and on the 6th (having attained a depth of 62·54 metres), the level was ·01 below the level of the ground.

From the 6th to the 13th January, the works were continued and pushed on to 68·75 metres. On the 13th, a second gush of water showed itself, which rose at length to 0·40 of a metre above the ground, but the piping became more and more difficult. A deviation of ·07 of a metre had already been noticed in the vertical projection of the column which caused friction at the bottom of the last pipe, the soupape à boulet continued to act, but the results were very poor. At one time, every effort that was made, could not overcome the resistance in sinking the column on account of the pressure of the sand against the sides. The situation was serious and very embarrassing. It was seen, moreover, that the hoop which protected the bottom of the first pipe was displaced, and that the "trépan" of the "soupape" struck it at every stroke and brought away fragments of it. It was necessary to use repeatedly the large trépan which entirely detached the hoop and ground it into small pieces. The crane which was lifted by the pressure of the jackscrews was successively charged with weights varying from 1,920 kilos to 5,070 kilos. Notwithstanding this pressure, the resistance was still great. The "soupape à boulet" continually brought up the débris of the hoop and the pipe to which it was rivetted; the work of boring was almost at a standing, and the crane continued to rise. It was then loaded with a total weight of 19,290 kilos. A small sounding probe was lowered down the tube, which penetrated to a depth of ·55 of a metre in the ground and brought away traces of bluish clay. The boring was then at 68·81 metres, which showed the depth sunk during the day to be only ·06 of a metre. The hydrostatic level which rose for a moment to 1·03 fell to 0·95, and, on the 16th January, was not more than ·25 of a metre above the ground. It rose and fell, alternately, from ·73 to ·69 of a metre, and eventually fell down to ·12 below the ground-level, while the tubes were not able to be driven in more than ·67 of a metre in a week.

The works were proceeded with nevertheless, but the results were very poor. We were however, on the point of overcoming the resistance to the driving in of the pipe. When the column had passed the water-bearing strata, the water caused an opening between the exterior of the pipes and the ground penetrated. From that time the work became easier; resistance diminished, and the "soupape" having reached the coarse sand, operations became a great deal more satisfactory.

On the 3rd February, there was a third gush of water, the hydrostatic level of which rose to ·38 of a metre above the level of the ground. The boring had then reached to 73·60

metres. This fresh gush of water, like the one which preceded it, made the sand flow back from ·50 of a metre to 1·20 metres into the interior of the tube. The work continued by means of the small soupape à boulet, and we then attained a depth of 79·34 metres.

At length, on the 13th February, after penetrating a stratum of very fine sand mixed with grits and remains of decayed wood, the hydrostatic level which had remained at about the level of the ground rose to ·52 of a metre, and continued under the impetus given to the work to rise gradually to 1·48 metres in twenty-nine days. This is the jet we now have. The water is very clear, does not taste bad, and boils vegetables perfectly. It marks 98 on the hydrometer. Its temperature is 34°30′.

The discharge of water was, on the 13th February, at 10 A.M., 140 litres; in the evening it was 268 litres; and to-day, the 20th March, it has reached to 666 litres a minute—a quantity more than sufficient to irrigate the Jardin d'Acclimatation. After several attempts to extract the bottom of the pipe, it was discovered that the force of the rising water brought up sand to the surface, and that the detachment had been effected spontaneously. The boring has reached to 79·52 metres. It took 89 days of 10 hours each of actual work. This gave an average per diem of $\frac{79.52}{89}$ = ·89 daily.

The following have been the general expenses:—

	F. C.	F. C.
Construction of the crane	1903·52	2570·55
Transport and setting up, &c.	662·03	
Value of 80m of pipes	2340·00	3420·00
Expenses of packing, freight and insurance	1080·00	
Hire for driving in the pipes	1630·12	1630·12
TOTAL		7620·67
		2570·55
		5050·12

If from this sum the cost of the crane be deducted, which was Fr. 2570·55, the real cost of the well will be only 5050·12.

This makes the cost of each running metre in boring $\frac{5050 \cdot 12}{79 \cdot 32}$ =63f. 50c.

This expenditure is really very small when we take into consideration the dreadful famine which raged through this country in 1877 and 1878 in consequence of want of water.

One can now assert with certainty after the success achieved in boring three wells within a radius of about 800 metres of each other, and at depths varying from 38·53 to 79·52 metres, that if the calamities which famines involve on the Coromandel Coast are not completely overcome, their disastrous consequences can be considerably mitigated by sinking artesian wells.

* * * * * *

This being the first attempt at boring to such a great depth in this country, I have thought that, from a scientific point of view, it would be useful to have in France a complete collection of geological specimens of the strata penetrated. With this view, I have caused a case containing an extract from the register of borings with all the specimens and four bottles of the water now issuing from the well to be deposited in the Magasin Général. I think M.l'Ordonateur that this case should be forwarded to His Excellency the Minister of Marine and Colonies, who would probably make it over either to the School of Roads and Bridges or the School of Mines.

(Signed) A. CARRIOL,
L'Ingénieur, Colonial,
Chief du Service des Points et Chausseés.

APPENDIX II.

Experiences of Mr. C. Poulain in the boring at the Savana Filature. Extracted from "Travaux des Commissions Locales," (Commissions des Puits Artésiens). Pondicherry, 1877.

L'outillage, dont il est inutile de donner le détail est celui employé pour le sondage à la corde appelé *sondage chinois* avec quelques modifications facilitant le travail dans les terrains que nous avons rencontrés. Nous avons employé pour tuber notre trou de sonde un tuyau en cuivre rouge de 14 centimètres de diamètre intérieur et d'une épaisseur de métal de Om 003m/m. La longueur de chaque tuyau variait de 2 m. 50 c. à 3 mètres. Ils sont réunis l'un à l'autre par un manchon de même métal et de même épaisseur fixé au moyen des rivets.

Un puits de service de 2 mètres de profondeur a été creusé et un échafaudage compos de 2 bigues et 1 traverse a remplacé la chèvre qu'il aurait fallu construire.

Tout étant prêt, le sondage a commencé le 18 février; nous nous sommes servi de la cuillère à soupape de Jobard. Nous étions dans cette couche de gros sable qui est très-employés dans le pays pour la fabrication du mortier. La profondeur était alors de 4 mètres, nous avions 50 centimètres de hauteur d'eau dans notre tube que nous descendions au fur et à mesure en le chargeant de gros poids de fonte et lui communiquant à force de bras un mouvement de va-et-vient au moyen d'un tourne-à-gauche formé de 2 pièces de bois à machoires boulonnées fortement sur le tuyau de tubage. Le travail marchait lentement, la quantité de sable ramenée étant très-faible. Les clapets s'engageaient souvent quoique nous ayons eu soin de garnir la charnière de ceux-ci d'un tube en caoutchouc au centre duquel passait la broche servant d'axe à ces clapets. De plus, l'écrou de retenue contre lequel il allait faire choquer le mouton à la montée pour opérer la fermeture des clapets, se détéri orait. Nous fûmes obligé, plusieurs fois, d'en mâter la tête. Enfin, l'écrou se cassa, lais sant remonter le mouton tandis qne la cuillère à soupape restait au fond du trou. Nous n'etions alors fort heureusemcnt qu'à 6 mètres de profondeur; ce qui permit de remener facilement la cuillère restée au fond. Nous travaillons toujours dans la même couche de sable mélé de quelques cailloux roulés, les uns blancs tels que ceux que l'on trouve au grand-étang es autres noirs, ternes et quelques-uns ayant un reflet rappelant le chatoiement de ces pierres connues sous le nom d'œil-de-chat. Nous avons également ramené de cette profondeur quelques pierres à arrêtes vives, nullement roulées, ressemblant à des débris de basalte et d'amphybole. Quelques-unes avaient une apparence verdâtre. Nous réparâmes la cuillère à soupape, mais craignant un nouvel accident, nous construisîmes une soupape à boulet qui fonctionna admirablement jusqu'à la profondeur de 7 m. 40 c. où nous rencontrâmes une couche d'argile noire mélée de même sable et de quelques cailloux. Au bout de quelques coups de sonde, nous ramenâmes des fragments d'argile noire qui formait une couche compacte à en juger par l'effort qu'étaient obligés de faire nos hommes pour dégager l'outil. Le travail marcha encore lentement, nous étions déjà au 13 février. Nous ne ramenions à chaque coup de sonde que de fort petites quantites d'argile; nous pensâmes que notre outil gêné dans sa chute par une hauteur d'eau de près de 4 mètres, n'avait pas assez de poids. Nous suspendîmes alors, au moyen d'un assemblage à boulon sur les tirants de la soupape à boulet, un cylindre en fer de 5 centimètres de diamètre et 25 centimètres de longueur. L'outil pénétra alors plus profondément dans la glaise et en ramenait fort peu encore. Nous adaptâmes alors au couteau circulaire de la soupape à boulet le couteau en croix de l'outil de Collet de Reims, ce qui eut pour résultat de diviser cette partie du cylindre en quatre compartiments présentant chacun une surface d'adhérence bien supérieure à celle

existant précédemment. Le travail marcha un peu plus rapidement et le niveau de l' eau baissant dans le tube à chaque coup de sonde, nous arrivâmes le 14 février au soir à 7 m. 80 c. La glaise devenait plus compacte et ne contenait presque pas de sable, nous y remarquâmes quelques paillettes nacrées, ayant à peine un millimètre carré de surface. Il nous vint ensuite des débris de coquilles nacrées très-molles à l'état humide se feuilletant sous l'angle. Nous restâmes dans cette couche jusqu' au 16 vers midi; l'eau avait disparu totalement du tube dans la matinée, ce qui indiquait que la couche de glaise était parfaitement imperméable. La profondeur atteinte était de 10 mètres environ. Dans l'après-midi, l'eau reparut dans le tube, nous étions alors à 10 m. 28 c. et nous retirâmes du fond du sable quartzeux, souillé d'argile noire. Après quelques coups de sonde, l'argile noire reparaît, l'eau qui était remontée dans le tube jusqu'à 3 m. 50 c. de la surface, rebaisse et finit par disparaître; nous continuâmes notres forages en versant de l'eau dans notre tube et ramenant toujours de la glaise noire bien plastique, pure de tout mélange. Nous continuâmes ainsi jusqu' au 17 au soir, nous etions arrivé à la profondeur de 16 mètres. Le tuyau de tubage descendait difficilement quoique nous ayions augmenté les poids de charge et le nombre de nos hommes agissant sur le tourne-à-gauche. Notre chef sondeur s'aperçut alors qu'il se produisait dans le tube un bruit ressemblant à la chute d'un jet d'eau dans le fond. Il était presque nuit close, nous arrêtames le travail. Le lendemain matin, le même bruit se produisait, mais le soleil était encore à l'horizon, il nous était impossible de rien distinguer dans le tube. Nous essayâmes à manœuvrer le tourne-à-gauche, la résistance était grande nous remarquâmes que le bruit de jet d'eau augmentait; nous descendîmes dans le tuyau une lampe allumée, placée dans un petit seau qui nous avait servi à prendre des échantillons d'eau dans les moments de repos.

Nous découvrîmes alors une fissure qui s'était produite à la soudure d'un des joints de notre tuyau. Nous décidâmes immédiatement qu'il fallait procéder au levage du tube pour en faire la réparation: après des efforts énormes au moyen de levier et de *Jack screw* le tuyau céda et vint avec facilité; mais une longueur de 11 mètres était restée dans le fond du trou de sonde et son extrémité supérieure était à 5 mètres en contrebas du sol. Nous fîmes aussitôt creuser notre puits de service jusqu'au niveau de la première couche aquifère; au moyen de plongeurs, nous coulâmes 2 m. 10 c. de couronnes en terre cuite, notre tuyau se trouva ainsi dégagé de 60 centimètres du fond du nouveau puits. Pour faciliter le travail des forgerons qui devaient redresser le tuyau et y placer un système d'arrachage, nous installâmes deux pompes à incendie du modèle de la ville de Paris. Enfin, le 28, tout le mal était réparé, nous avions de plus vidé le tube de sondage qui s'était rempli jusqu'au fond et nous étions redescendu au point où l'accident nous avait surpris. Nous sommes toujours dans la même couche d'argile noire et compacte, l'eau a complètement disparu le 28 à midi et nous sommes à 16m. 58c. Vers la fin de la journée, l'eau reparaît un peu, nous espérons que c'est une couche de sable, nous donnons quelques coups de sonde, nous ramenons toujours la même argile, l'eau cependant, semble monter encore, nous en sommes inquiet, nous rappelant notre premier accident. Le tube est dur à manœuvrer; nous parvenons toutefois à le descendre de quelques centimètres en donnant un léger mouvement de va-et-vient; un dernier coup de sonde nous donne un peu de sable mélangé à l'argile. Il était presque nuit, on arrête le travail. Quel ne fût pas notre étonnement le 1[er] mars au matin, de trouver notre tube plein et débordant légèrement à une hauteur de 1 mètre en contre-bas du sol! L'écoulement est très-faible et n'est appréciable que lorsqu 'on est près du tube nous arrêtâmes alors la descente du tube et nous fîmes sonder jusqu'au soir en travaillant au-dessous de celui-ci. L'outil même se prenait quelquefois, en remontant, au rebord inférieur du tuyau. Toute cette journée, nous avons ramené tantôt de l'argile pure, tantôt de l'argile mélée de sable gros et fin. L'écoulement de l'eau, dans les moments de repos, continue, il augmente légèrement à mesure que le travail avance; le 2 au matin, le tube st plein et déverse un filet encore très-mince à un mètre au-dessous du niveau du sol.

du sol, soit 10 centimètres de plus que précédemment. Nous attribuons cette différence à ce que notre tuyau était plus étanche, ayant pris pour le nouveau sondage la précaution de souder à l'étain tous nos joints de tuyau rivés. Nous avons continué le fonçage dans ces sables et nous avons comme précédemment trouvé à 27 mètres de profondeur une couche de glaise que nous avons traversée. Son épaisseur est de 6 mètres environ. La sonde a rencontré ensuite, c'est-à-dire à 33 mètres de profondeur, une couche de sable gris, d'une finesse extrême, fluide et même visqueux, qui a monté rapidement d'un mètre dans le tuyau de retenue et a engagé une première fois notre soupape à boulet que nous avons retirée avec grande peine en nous servant de la traction produite par un treuil double. L'eau qui jusque-là s'était maintenue à une assez grande profondeur, monta jusqu'au niveau du sol: c'était une nouvelle nappe qui se faisait jour. Après quelques coups de sonnette, notre outil a pénétré plus profondément et une poussée subite de 1 mètre 60 de sable se produisant dans le tuyau, la soupape s'est trouvée très-fortement engagée et a résisté aux tractions les plus puissantes que nous ayons pu exercer. Nous introduisîmes alors une soupape à boulet d'un plus petit modèle, n'ayant que 0 mètre 06 cent. de diamètre et qui, pouvant fonctionner dans l'intervalle laissé libre par le câble de la grande soupape, nous permit de ramener peu à peu un volume de sable équivalent à 50 centimètres de hauteur dans le tuyau. C'est le plomb de sonde qui nous a fourni cette donnée. Nous nous apperçumes alors que le couteau circulaire de cette petite soupape entamait notre câble au fond et en ramenait des fragments à l'état de filaments délayés dans la masse du sable. Nous construisîmes à la hâte avec un bout de tuyau une soupape à clapet de plus petite dimension encore, soit 0 mètre 0 4 cent. de diamètre, munie d'un couteau circulaire en bois et d'un clapet de cuir chargé d'une plaque de plomb. Nous ramenâmes fort peu de sable et il contenait toujours des filaments de chanvre. Pensant que ces filaments provenaient de l'opération précédente, nous persistâmes à nous servir de ce nouvel outil. Après vingt heures de travail, les filaments venaient toujours et en grande abondance. Craignant de détériorer notre câble, nous renonçâmes donc à ce moyen de dégager notre outil.

Nous fîmes alors descendre dans la colonne de retenue, à 32 mètres de profondeur le tuyau en toile, armé de sa lance, d'une de nos pompes à incendie, au moyen de laquelle nous injectâmes vivement au fond du sondage une forte quantité d'eau qui produisit un courant ascensionnel ayant assez de vitesse pour ramener de cette profondeur une grande quantité de sable fin. Au bout d'une heure, nous jetâmes le plomb de sonde qui accusa une profondeur de 33 mètres 50. Nous soulevâmes alors de 30 centimètres notre tuyau de retenue en faisant agir en sens contraire notre presse à vis et le tuyau monta sans effort. En même temps un homme imprimait au câble des mouvements de torsion et de fouet, l'outil se trouva dégagé. Le câble n'a éprouvé qu'un peu d'éraillement dans une partie; les filaments provenaient principalement de l'extrémité libre de l'attache.. Cet accident nous a mis aux prises avec l'un des cas les plus communs dans les terrains éboulants et fluides du genre de ceux que nous traversons. L'eau se maintient à 90 centimètres au-dessus du sol, et à ce point elle ne donne pas d'écoulement. Nous avons goûté l'eau de cette dernière nappe, elle nous a paru bonne.

Cette couche de sable n'a qu'un mètre d'épaisseur; elle ne pouvait donc nous fournir un écoulement important. Nous trouvâmes ensuite une nouvelle couche de glaise, toujours de la même nature que les précédentes c'est-à-dire noire, plastique, compacte. Quelques rares cailloux noirs et schisteux comme précédemment ont été aussi ramenés par la sonde. Le niveau de l'eau s'est abaissé dans la colonne de retenue aussitôt que celle-ci a pénétré dans la glaise. L'épaisseur de celle-ci n'est que de 2 mètres environ; il nous est venu ensuite du sable siliceux, à gros grains, souillé d'un peu de glaise; nous sommes à 36 mètres 50 de profondeur et l'eau se tient à 1 mètre en contrebas du sol au moment où nous terminons cette note.

C. POULAIN.

Pondichéry, le 20 Juillet 1877.

Le dernier compte-rendu de nos essais s'arrêtait à la profondeur de 36 mètres; nous étions alors dans des sables à gros grains souillés de glaise. A 37 mètres, nous trouvâmes une argile moins noire que celles rencontrées précédemment, sèche et contenant des grains de concrétions calcaires variant de 1 à 5 millimètres cubes et d'autres un peu plus gros. Cette couche d'argile contenant parfois un peu de sable, tantôt mêlé dans la masse, tantôt par bandes minces, a continué jusqu'à 45 mètres, soit donc 8 mètres d'épaisseur pour cette couche imperméable. Notre sonde ramena ensuite de la même glaise mêlée de cailloux roulés, la plupart, de la grosseur d'un pois, les uns blancs, les autres noirs, d'autres un peu plus gros. Puis, l'argile disparut et il nous vint de gros sables avec les mêmes cailloux dont quelques-uns, de quartz bien pur et hyalin tels que ceux que l'on trouve au Grand-étang dans le ***Ravin des chauves-souris*** et ailleurs et que quelques personnes ont fait tailler et monter en bijoux; à cette profondeur, l'eau a atteint près d'un mètre audessus du sol et a déversé légèrement quelques minutes seulement, pendant le travail, puis est redescendue à 70 centimètres plus bas,

A 46 mètres les cailloux deviennent plus rares, le gros sable est mêlé de sable fin, gris, fluid, du genre de celui rencontré précédemment à 33 mètres. Le travaile devient très-lent quoique nous nous servions d'un treuil simple pour la descente et la montée de notre outil. L'élasticité de la corde augmentant avec sa longueur (46 mètres) rend la manœuvre moins précise et plus pénible. Le tuyau descend difficilement; nous sommes souvent obligé de le soulever pour le descendre ensuite. A mesure que nous pénétrons dans cette couche, les cailloux deviennent de plus en plus rares; les grains de sable sont très-gros et presqu'entièrement composés de débris de quartz hyalin de 2 à 3 millimètres cubes de volume environ. L'eau, pendant les moments d'arrêt, monte très-lentement et s'arrête à 30 centimètres au-dessus du sol. Nous étions à la profondeur de 46m 50c lorsque la sonde nous ramena quelques petits débris d'argile blanche, en partie delayés dans l'eau; nous pûmes cependant en trouver un de la grosseur d'une noisette qui nous a permis d'en examiner les caractères qui sont les suivants: elle ne fait pas effervescence avec les acides, happe fortement à la langue et prend un poli admirable sous le frottement de l'ongle, c'est du kaolin. Les cailloux de quartz et les quelques débris d'argile indiquent que l'alluvion les a enlevés aux terrains tertiaires.

A 47 mètres, le grain du sable est moins gros que précédemment, il ne contient presque plus de cailloux roulés; à 48 mètres, le sable de rivière est un peu mêlé de sable fin ressemblant au sable de mer, il vient encore quelques fragments d'argile blanche. Puis les sables alternent, tantôt fins, tantôt gros; nous y remarquons des débris d'argile calcinée noirâtre et des fragments ressemblant à la brique du pays; nous hésitions cependant encore à croire à la presence de briques lorsque la sonde nous ramena de petits tessons de poterie commune; (nous donnons ce dernier renseignement sous toute réserve, car il peut se faire qu'ils aient été projetés du sol.) Nous étions alors à 49m 90, l'eau se tenait à 50 centimètres au-dessus du niveau du sol quand tout-à-coup, à la suite d'un coup de sonde, elle monta très-rapidement et déversa au-dessus du tube de retenue dont l'orifice était à près d'un mètre au-dessus du niveau du sol. Nous fîmes suspendre le sondage dans le but de ne pas contrarier cette nouvelle nappe qui semblait se faire jour espérant qu'elle deviendrait spontanément abondante. Nous remarquâmes, pendant l'écoulement qui dura environ 5 à 6 minutes et que nous estimons supérieur à 10 litres par minute, que l'eau avait un mouvement alternatif de montée et de descente dans le tuyau: quand l'écoulement cessa, l'eau baissa rapidement. Nous fimes alors donner un coup de sonde qui ramena du gros sable mêlé de boulettes d'argile noire de la grosseur d'un pois, puis toujours du sable tantôt fin, tantot à gros grains et par fois les deux sables mélangés, souillés d'un peu d'argile noire delayée.

A 51 mètres, la sonde nous ramena des débris de psammite friable et teintée par de l'argile

ocreuse, jaune et mêlés de sables, de cailloux roulés et de quelques parcelles de calcaire dur d'un blanc grisâtre. L'argile ocreuse jaune teinte les sables et l'eau qui est fortement jaunâtre. A ce moment, le travail cesse d'avancer en profondeur quoique la soupape revienne chaque fois entièrement pleine de sable. Celui-ci monte dans le tuyau dont la longueur totale est de 52m 68 et le plomb de sonde n'y accuse qu'une profondeur de 51m 75. Ces sables semblaient inépuisables; après deux jours entiers de travail, nous étions toujours au même point; enfin le troisième jour la poussée du sable s'arrêta et 'outil put descendre à la profondeur de 52m 68, L'eau monta au fur el à mesure que nous dégagions les sables et elle déversa au-dessus de notre tube par tous les trous de rivet avec une certaine force; l'extrémité supérieure de notre tuyau était alors de niveau avec le sol environnant. Un petit accident arrivé à notre soupape à boulet nous obligea de suspendre pour deux heures notre travail. L'eau coula et sembla augmenter un peu et de jaunâtre qu'elle était, elle devint assez limpide. La soupape étant réparée, nous continuâmes à dégager et il nous vint deux ou trois fois du sable á gros grains noirâtres, puis des débris de grès ferrugineux (psammites) de couleur brun-foncée, moins friable que précédemment, mêlés dans la masse de sable blanc à gros grains légèrement souillé d'argile ocreuse jaune. L'eau augmenta sensiblement pendant le travail que nous arrêtâmes à 6 heures du soir; elle coula toute la nuit suivante et le matin elle se trouva d'une limpidité parfaite. Nous recueillîmes le produit de cette source dans un vase jaugé, nous trouvâmes que le débit était de 48 litres par minute. (10 Septembre 1877, 8 h. matin.)

Voici les remarques que nous faisons sur l'eau, elle est bonne au goût, sauf une saveur métallique très-légère qui tend à diminuer au fur et à mesure de l'ècoulement; le nitrate-d'argent y produit un léger nuage opalin et le tannin n'y donne aucune coloration. La température de l'eau à l'orifice du sondage est de 33 degrés centigrades. Le point de déversement actuel est de 30 centimètres au-dessus du niveau du sol environnant.

Nous continuons à dégager le fond du trou de sonde dans l'espoir que le débit augmentera et nous avons fixé notre tuyau pour l'empêcher de descendre plus bas.

Une seconde expérience faite dans la même journée accusa un débit be 66 litres par minute. Le lendemain (11 Septembre) à 8 heures du matin, le débit est de 90 litres par minute au moment où nous terminons cette note; nous conservons l'espoir d'une nouvelle augmentation.

C. POULAIN.

Pondichéry, le 11 Septembre 1877.

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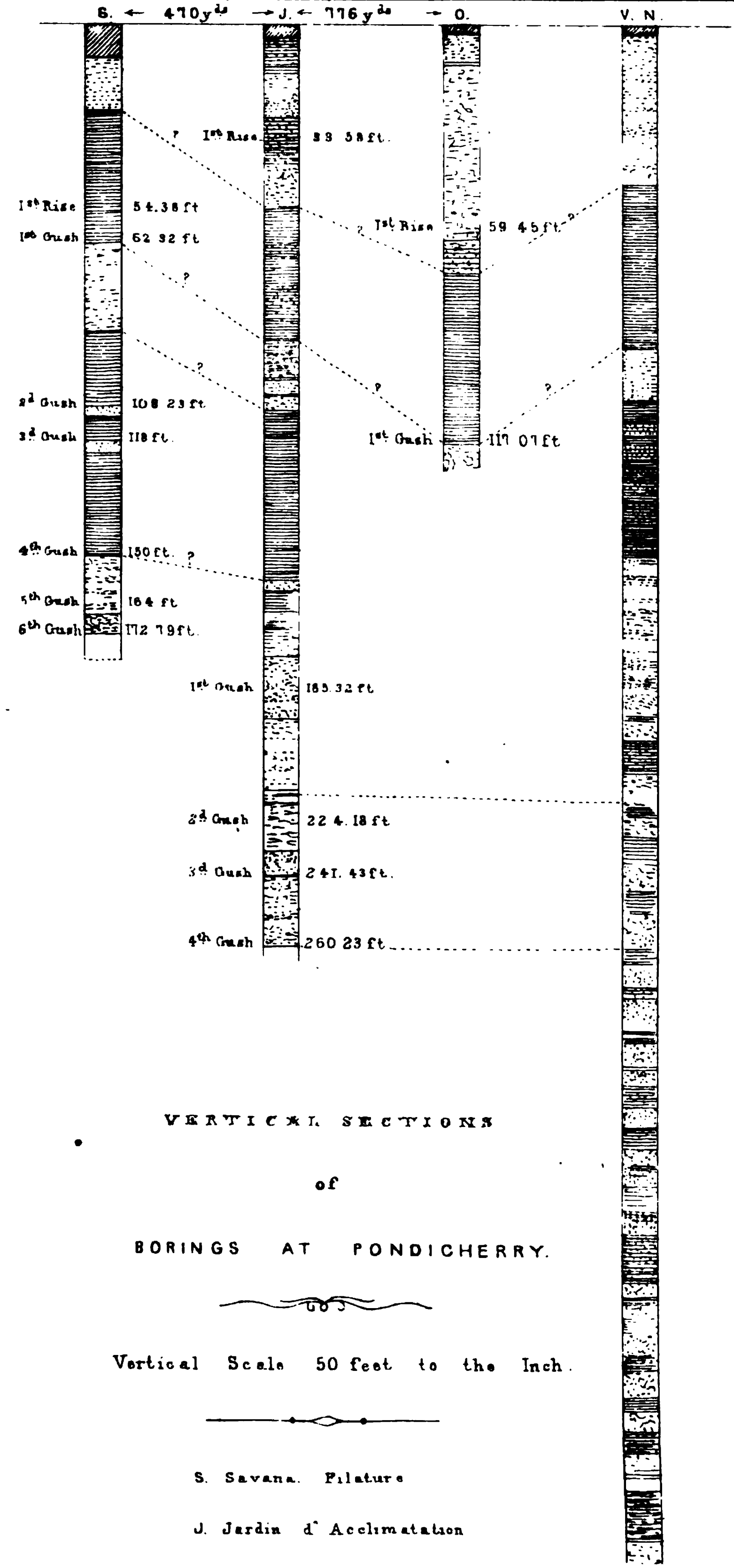
SURGEON MAJOR J. E. TIERNEY AICHISON,
Botanist to the Kurum Field Force.

Stibnite (antimony sulphide) from Embinpilly on the Godavári.

P. VANSTAVERN, ESQ.



VERTICAL SECTIONS

of

BORINGS AT PONDICHERRY.

Vertical Scale 50 feet to the Inch.

S. Savana. Pilature

J. Jardin d' Acclimatation

O. " "

V. N.

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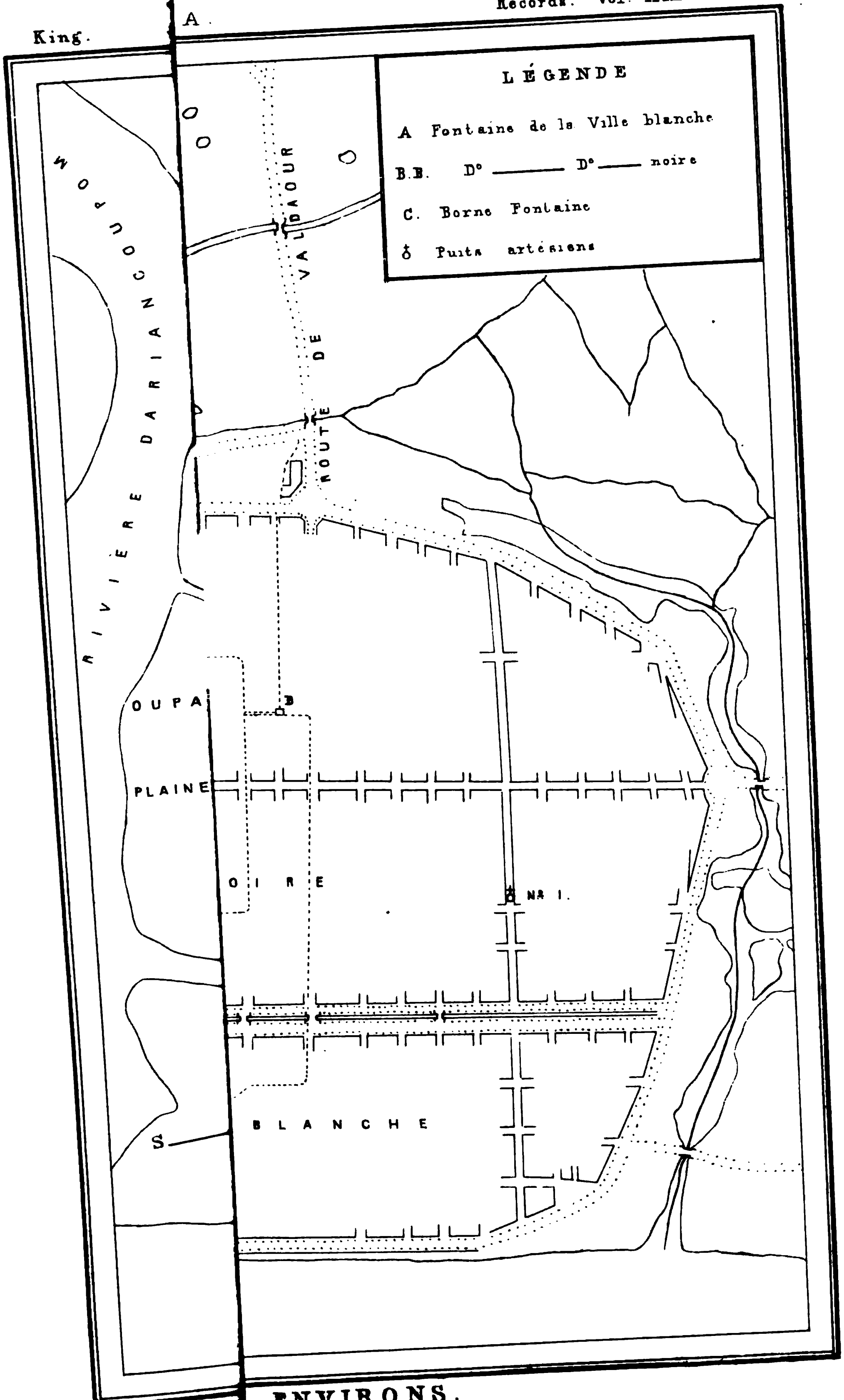

On Stone by ENVIRONS.

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THE KUMAUN LAKES, *by* W. THEOBALD, *Deputy Superintendent, Geological Survey of India.*

I cannot better preface my own notes on the Kumaun lakes than by briefly adverting to the views regarding their origin, propounded by my colleague Mr. Ball in the Records of the Geological Survey, Vol. XI, part 2, page 174; since differing so essentially, as I do, from them, it will be more convenient to specify at the beginning wherein this divergence of opinion consists, than to break the thread of my own description by constantly-recurring allusions to Mr. Ball's paper.

I make no affectation of approaching the discussion of the vexed question of the origin of the Kumaun lakes without any bias for any particular theory, since believing, as I do, in the strongly presumptive universality of glacial conditions during the great ice age, the result of cosmical rather than local causes, it would be absurd in me to disavow any expectation of finding traces of such conditions within the Himalayan region, of all others, or to deny that such conditions may not be held to afford a plausible *primâ facie* explanation of the origin of these lakes, deserving of all our respect, till it can be demonstrated that such a presumption is erroneous. Such an error, supposing it to be one, is, or should be, very capable of disproof, and I understand Mr. Ball's paper to be such an attempted disproof, but, in my opinion, an unsuccessful one.

The Kumaun lakes have so many points of resemblance in common, both as regards elevation, physical surroundings, and geographical arrangement, that it seems not unreasonable to assume a common origin for them all, so that I shall attach less importance to the elucidation of the history of those presenting obscure features, than to the endeavour to establish satisfactorily the origin of one or more of them; and I herein differ from Mr. Ball, in that, whilst he can discern no conclusive proof of glacial action in any of those visited by him, I consider

the case fairly, not to say strongly, made out as regards some, and capable of being extended by analogy, and in default of any sufficient reason to the contrary, to all.

Mr. Ball (p. 175 *l. c.*) commences by dividing the Kumaun lakes into three classes "having certain features mutually in common," but unfortunately without specifying what these features are; an omission which must be my excuse if I fail in consequence to do justice to my colleague's views on the subject. Passing to the consideration of Naini Tál (of which a pretty lithographed sketch is given) Mr. Ball seeks to controvert the views of those who attribute a glacial origin to its basin, but quite unsuccessfully, I think. Whether this lake really lies in a true ice-cut basin or basins, is certainly not established or likely to be so by actual proof, unless the lake is ever drained, a contingency which may be dismissed from present consideration, though if Mr. Ball's section of its basin represents the general contour of its bottom, and not the contour along a single line only, there is the strongest presumption in favour of its glacial origin. I do not, however, think it necessary now to dwell at any length on Mr. Ball's speculations as to the probable nature of the bottom, but there is one remark of my colleague touching the mode in which the rock basins (supposing them to exist) have been produced, which indicates so absolute a divergence from the current ideas respecting the *modus operandi* of ice action, that I do not like to pass it without remark. Mr. Ball's words are (p. 176 *l. c.*) "supposing it to be so, the twin basins might be readily explained by the hypothesis that they had been successively excavated by the retreating end of a glacier." This is perfectly unambiguous as far as language goes, but does Mr. Ball really suppose that a glacier ever moves backwards, and if not, then what does he mean by the above words?

A glacier does its work by its weight and momentum; its movement is solely *forwards*, not necessarily downwards, but simply forwards, and away from the direction of its source. The "retreating end" of a glacier, therefore, cannot excavate in any degree, or add in its retreat, to the work it had already performed in its advance; since the word "retreat" does not involve here any sense of *retrograde motion*, but simply a contraction of the dimensions of the glacier induced by the operation of climatal causes. As the end of a jet of water *retreats* as the pressure under which the jet issues is diminished, without, however, the particles which compose the jet losing their forward motion (though its amount may be reduced), so it is with a glacier, and I am therefore at a loss to know whether, in the passage quoted, my colleague's words correctly express his meaning.[1]

I do not consider either that Mr. Ball has been particularly felicitous in his efforts to dispose of the argument adduced by Mr. H. F. Blanford for the glacial origin of the lake, from the peculiar shape of the basin, and the character of its sides, unbroken by subordinate ridges and spurs.

[1] Mr. Ball may perhaps be credited with the meaning his words would suggest to most of his readers—that the upper basin had been cut after the glacier had retreated from its position of maximum extension.—H. B. M.

Mr. Ball observes:—"It is true that there are no subordinate ridges and spurs, but such is not uncommonly found to be the case, where valleys run with the strike between hard beds, bounding softer ones, which have been eroded to form the valleys." The picture here drawn is suggestive of some great synclinal valley in Vindhyan sandstones, or in some similar group characterised by the parallelism and unbroken character of its beds, and there are doubtless many valleys which might have 'sat for the portrait,' but the entire force of the argument, as here used, depends on its applicability to the Naini basin. Of course, by introducing it in this connection, Mr. Ball implies that it is *so* applicable,—a view which I am wholly unable to coincide in. Mr Ball, however, having created the impression which the above sentence is calculated to convey, nowhere else lays special stress on the parallelism of the strata bounding the basin, but speaks of them as in places "much contorted and broken," and of the limestones "near the depôt" forming "irregular lenticular masses, not as beds." The fact is, the valley wherein Naini Tál nestles is surrounded by rocks, varying greatly in structure, such as splintery schists, and massive limestones, which agree in one character only, that of being very disturbed, as regards their stratigraphical arrangement, and much crushed and mechanically disintegrated as regards their petrological condition. This last condition (certainly one not unfavourable to the production of spurs by denudation) causes the hill sides to be much marked by debris (landslips perhaps Mr. Ball would say), washed down over them, but in the shallow road cuttings along the 'Mall,' the true arrangement of the strata may be seen, not as might be inferred from Mr. Ball's words, with a surface-plane and strike, coinciding with the axis of the valley, but revealing highly disturbed beds, with their ends truncated at various angles by the surface. Opinions may differ as to the value of the evidence in question, but the stratigraphical idea which Mr. Ball's words convey is certainly not that most obviously indicated on the ground.[1]

Mr. Ball also alludes to "the rigid trap axis" of the hill, but this feature I consider no less suppositious than the implied parallelism of the beds bounding the lake. I was much surprised, after what I had read of the lake, to see so little trap in its vicinity, but much of the rock in the district which might be so termed in a petrological sense, I should prefer to regard as an integral member of the schist group. Beds of this character may occur in the range in force, but to speak of them as "trap" without further comment, is, I think, likely to mislead, especially in helping to confuse their relationship with the eruptive trap, properly so called, so largely developed about Bhim Tál and Malwa Tál. Mr. Ball, moreover, does not very clearly explain in what precise way the presence of either bedded or eruptive trap confers rigidity on the range in question, and in default of a fuller exposition of Mr. Ball's views on the subject, I am unable to recognise a greater amount of "rigidity" in the hills about Naini Tál, than in any other hills in this or any other district. Did the ranges environing Naini Tál consist

[1] To most geologists Mr. Ball's words would probably suggest a valley of erosion on a broken anticlinal flexure: a condition compatible with what he claims for the case and with the facts adduced against it in the text.—H. B. M.

of soft sands and clays banked up against a "rigid trap axis," I could appreciate the dynamical appropriateness of the expression, but not so, where the ranges consist of schists and massive limestones, and the very existence of a marked or strongly differentiated axis of a more rigid character is, to say the least, a matter of the purest supposition.

Equally is Mr. Ball at variance both with Mr. H. F. Blanford and myself regarding the nature of the barrier at the outfall of Naini Tál: Mr. Blanford and myself both regarding it as a moraine, whilst Mr. Ball terms it a landslip; and I may here remark that to "landslips" (so far as I can gather) all the Kumaun lakes are, in Mr. Ball's opinion, due.

As regards the particular case of Naini Tál, it may be seriously objected to Mr. Ball's view, that the barrier is not placed where the sides of the valley are steepest, nor is the slope sufficient to suggest such a cause. A general idea of the objection here taken by me, may be gathered by referring to the sketch of the lake given in Mr. Ball's paper; but it requires a personal knowledge of the ground to realize how much bolder the slopes are at other parts, where no obstructive landslips have descended, than at the actual outfall. It may be suggested that the very descent of the "slip" has itself lowered the slope, and modified the profile of the neighbouring ground, but I do not think such is the case either here or anywhere else, and I merely allude to the notion, to prove that it has not escaped consideration. A few words will not be here out of place, touching the effects produced by a 'landslip' as contrasted with those due to a 'moraine.'

A landslip in its proper and original sense, is a somewhat rare phenomenon, (depending on certain conditions of surface, subsoil, and drainage), such as the 'undercliff' in the Isle of Wight, and such cases as quoted in White's 'Selbourne', but which are rare in the Himalayan region, though not unknown in the Salt-range. The term is, however, also applied to one of the commonest phenomena in hilly regions, the descent from a steep hill or cliff, of a mass of rocky materials, detached partly by frost perhaps in the first instance, partly by water and partly by gravity; the initial movement where the mass is considerable being possibly in some cases due to an earthquake. This being the sort of phenomenon considered by Mr. Ball as being the cause wherefrom all the Kumaun lakes have originated, it is necessary carefully to consider how far the conditions present in such cases resemble or differ from those connected with moraines, and whether they are adequate to the production of the results attributed to them. Such 'slips' as I now allude to may be broadly divided into two classes, namely, those which consist mainly of rocky fragments, detached from a steep hill side, always more or less angular and often of a large size, and 'slips' from ground where the rock is more sandy or argillaceons, and in which water is more or less the prime mover; the result being the descent, often very gradual, of a heterogenous mass of mud and stones, whose power of progression is regulated partly by the slope over which it moves, and partly by the amount of fluidity of the ingredients composing it. Slips of rock fragments of the first class are, as a rule, sufficiently obviously connected with the source whence they are derived, and stand usually at a considerable angle, the slope varying, however, with the

size and character of the materials composing it. To no such origin as this can, I think, any of the barriers of the Kumaun lakes be attributed. 'Slips' of the second class, however, far more closely simulate a 'moraine,' but those possessed of most mobility, from the greater fluidity of their composition, are in the precise ratio of such fluidity least capable of withstanding removal by rain, or of bearing upon their surface craggy masses of rock such as I should term 'erratics,' and which, if not numerous, are at all events occasional and most significant constituents of some of the barriers. Mr. Ball mentions masses of rock 10 feet in diameter, as forming part of the barrier of Naini Tál, but this is an under-estimate, as some of the masses are double and treble that size. They have certainly not fallen from any neighbouring cliff, nor are the harsh comminuted rocks in the vicinity of the lake capable of forming a stiff mud on which they could have been transported, after the fashion of a 'moraine,' and the inference I therefore draw from them is, that they are really part of a 'moraine' and not brought into their present position by any of the ordinary modes of stream action.

Of Bhim Tál, Mr. Ball's account is hardly more satisfactory, in my opinion, than in the case of Naini, with the important exception, that he himself sees a serious objection to the application to it of the 'landslip' theory. Mr. Ball's words are: "Towards the southern end of the lake on the eastern side, there is a *boulder deposit*, which extends along the bank, up to a level of perhaps 10 feet above the water." Now, this "*boulder deposit*" is, according to my interpretation, part of a lateral moraine which descended from the peak above Sangri (6,320 feet), and in conjunction with that of the main glacier to the south, helped on the diminution of glacial conditions to block the direct exit of the valley to the south, thereby creating the lake. Mr. Ball goes on to add: "The most remarkable feature about it, however, is, that it is backed by no high range on the east, so that, if derived from a landslip, the materials must have come from the west, and of necessity *temporarily* filled up a *portion* of the bed of the lake." I do not see by what stretch of ingenuity Mr. Ball can defend the above sentence from the charge of very inadequately conveying the true state of the case. The course of the lake, so far as the "boulder deposit" extends, runs north and south. As there is no high ground to the east, the material, as Mr. Ball owns, if the boulder deposit originated in any way in a landslip, must have come from the west across the lake, but in so doing must have *obliterated* it altogether. To talk of this as temporarily filling up a portion of its bed is simply trifling with the intelligence of the reader. There being no scour, how does Mr. Ball suppose such a mass of materials to have been removed, and the bed of the lake cleared of its temporary obstruction?

Mr. Ball is further forced into the admission, very remarkable in his mouth, with reference to this "*boulder deposit*," that "its appearance suggests a moraine," though this is not very consistent with the appellation he bestows on it.

In considering, too, the question of the descent of a glacier down the valley from the north-west, Mr. Ball allows himself to be influenced by a difficulty which I confess I am far too dull to perceive the force of. So far as I can understand it, the difficulty, as it presents itself to him, is the possible or probable

prolongation of a spur of rock across the valley, which, I understand Mr. Ball to argue, would be a serious, not to say insurmountable, difficulty in his mind to the idea of a glacier ever having passed along it. To me it is nothing of the sort; for I can conceive no sort or description of spur blocking or constricting a valley which could offer any bar to the passage of a glacier: for the plain and simple reason, that wherever the stream which originally excavated the valley could go, a glacier could follow, and is, moreover, not so bound by hydrostatic laws as water is in its fluid state. Further into the matter than this I confess my inability to see.

Of Naukatchia Tál and Sáth Tál Mr. Ball expresses a confident opinion that their shape and surroundings preclude the idea of glacial agency being concerned in their formation, an opinion from which I profoundly dissent, especially with reference to the former lake, which I consider one of the most remarkable lakes in Kumaun, if not in the world, as I shall endeavour soon to show.

There is one remark in Mr. Ball's "*conclusions*" (p. 181 of his paper) which I cannot pass without comment, as I am painfully compelled to own I do not realise its cogency. The remark is couched in the following words :—

"There is one point geologically which links the three larger lakes together, and that is the occurrence of trap dykes in the vicinity of each." Is it reasonable to ask us to accept this dictum for argument? Is it not rather like clothing with scientific importance the crude geographical conceptions of honest Fluellen, touching the similarity between Monmouth and Macedon, as proved by their both commencing with the letter M? Why, too, the smaller adjoining lakes should be excluded from participation in the argument supposed to accrue from the presence of the dykes in the vicinity of their larger brethren, is not obvious. However, my colleague goes on to explain himself: "Now, I do not think it at all probable that the lakes are due to the original outburst of trap," an opinion in which I fully coincide, considering that such an idea is wholly beyond the bounds of the wildest possibility; but my colleague at once goes on to add: "But it seems not improbable that when the great upheaval and disturbance of the rocks of this area took place, the existence of comparatively rigid lines of trap may have been largely instrumental in determining the form which the surface assumed, and that on their flanks the soft shales, &c., may have been so much crushed and broken as to yield more easily to the subsequent operations of denudation, thus affording an abundant supply of materials for landslips, which ultimately served to close the valleys and form the lakes."

The two prominent ideas here presented are *firstly*, that "*rigid lines of trap have determined the form*" of the ground surrounding the lakes; and *secondly*, that the lakes are merely accumulations of water, dammed up by the "*abundant supply*" of soft shales washed off the flanks of the 'rigid lines of trap' in question. To this I can only say that the very existence of any such "rigid lines" is a matter of pure supposition on Mr. Ball's part, without the slightest evidence, so far as I am aware, in support thereof; and so far from the barriers which hold up the lakes

[1] The presence of an obstructing spur here has more weight against the glacial hypothesis than the absence of such spurs at Naini has in favour of it.—H. B. M.

being composed of 'soft shales,' it would be very hard to find such soft shales in any of the barriers I have examined. This is a plain issue. Are the barriers mainly composed of soft shales, or is that material mainly conspicuous in them by its absence?

Now, Mr. Ball himself tells us nothing about "soft shales" in the body of his paper. He therein describes the hills surrounding the lakes as consisting of "shales," "quartzites," "limestones," "argillaceous schists," "massive limestones," "highly indurated, but slightly calcareous mudstones," "white and purple quartzites," "greenstone," "trap," and even "granite and gneiss" (possibly) as members of the rock series of the district, but not a word of "soft shales" till we come to his 'conclusions,' wherein they are described as swathing his "rigid lines of trap," and by the "abundant supply of material" they have afforded, actually choking up the valleys, and thereby originating the lakes. In a word, Mr. Ball concludes that the Kumaun lakes have no connection whatever with former glaciers, but are due to landslips operating on soft shale, and the (to me) somewhat obscure influence of "rigid lines of trap." My own reason for regarding these lakes as glacial I shall now proceed to state.

The lakes of Kumaun may be divided into two groups,[1] *viz.*, those which lie in the direct course of an old glacier, and which may or may not occupy an ice-cut basin, and those formed by the occlusion of a valley by the projection across it of the material of a 'moraine.'

Class I embraces Bhim Tál, Malwa Tál, Naini Tál, the lowest of the Sáth Tál group, and an unnamed lake above Khurpa Tál.

Class II embraces Naukatchia Tál, Khurpa Tál, Suria Tál, and the upper lakes of the Sáth Tál group.

The origin of all is, however, identical, and putting aside all considerations of rock basins, which I have no immediate means of verifying, is due to the obstruction of local drainage, caused by the debris of old moraines on the retrocession of the glaciers at the termination of a glacial epoch.

The three principal lakes of Kumaun, Naini Tál, Bhim Tál, and Malwa Tál are situated in three separate, but parallel and adjacent drainage areas, the axis of each of which has a general south-east and north-west trend. The tract of country comprising this area is bounded on the north by so much of the hill range as extends from the vicinity of Gagan peak (7,855 feet) on the east to the Deoputhar peak (7,989 feet) on the west. Naini Tál lies a little below a horse-shoe shaped *cul de sac*, between the Deoputhar and Chini peaks, and is not only the largest (slightly) of the three, but the nearest to the culminating ridge, and whose basin may be said to display more obviously than the others the action of ice in its shape and character.

Its effluent waters give rise to the Balia river, which after a short south-easterly course, joins the Gola river a little below Ranibágh. Bhim Tál receives the drainage of the heights north of Bhuwali, from which it bears exactly south-east, while 7 miles beyond it, in the same direction is situated Naukatchia Tál

[1] For a map the reader is referred to Mr. Ball's paper (*l. c.*).

(the deepest of all the lakes according to Mr. Ball), the peculiar features of which I shall describe further on. Malwa Tál is simply an expansion of the Kalsa river, which with a south-easterly course drains the Gagan peak and adjoining heights, the drainage of all and the whole group of associated lakes being ultimately conveyed into the Gola river.

Bhim Tál and its neighbour Naukatchia Tál are separated from Malwa Tál by a lofty range with peaks from 6,413 to 6,320 in height; whilst from Naini Tál, Sáth Tál, and the lakes which drain into the Balia river, they are separated by a somewhat lower range of only 5,820 feet in height.

The most remarkable lakes are Bhim Tál and Naukatchia Tál, and their peculiar relation to each other renders it desirable to consider them together.

BHIM TÁL & NAUKATCHIA TÁL.

Even the new 1-inch maps of the country give no adequate idea of the peculiar features of the drainage of these two lakes. For example, the villages of Dhansila and Padani are situated on opposite sides of the stream which conveys away the surplus waters of Bhim Tál, a fact that it would be impossible to surmise from the map; indeed so far as I can make out, no escape whatever for the surplus waters of Bhim Tál is shown on the 1-inch map. One thing is apparent on the ground, and has been noticed by Mr. Ball, that the present drainage of Bhim Tál does not appear to be in the same direction as that it originally pursued, and I would extend the remark to Naukatchia Tál as well. Bhim Tál and Naukatchia Tál both stand in the same general south-east line, but the actual drainage line between them is slightly deflected on one side by the ridge on which Dhansila stands. At present the surplus waters of Bhim Tál make their escape about the centre of the lake on its east side, flowing under Dhansila (that is, to the north-east of it) with a prevailing south-east course as already stated. But there can be very little doubt that the original exit of the waters of the main valley, of which a submerged section now constitutes the present lake, was directly to the south and to the west of Dhansila instead of to the north-east of that village. My explanation of course is, that the escape waters found a readier passage through the lateral moraine skirting the east bank of the lake, than at the original point of discharge to the south, through and across not only the accumulated materials of the principal moraine, but the added accumulations of the eastern or lateral moraine (Mr. Ball's '*boulder*' *bed*) and a similar accession from the western slopes, which all helped to jam the throat of the gorge to the south. Be this as it may, the surplus waters now find their way beneath Dhansila, flowing to the south-east, till at a little less than halfway to Naukatchia Tál they are met by the surplus waters of that lake, flowing in an exactly opposite direction to the north-west. The hydrographical situation is peculiar, not to say embarrassing, but the result is, that the united waters of both lakes are deflected at almost a right angle to their joint courses, and flow to the south-west, through a narrow gorge in the trap ridge on which Dhansila stands, into the Gola river. Resuming our course from the above junction, in a south-eastern direction, and which would be called *down* the valley, but for the anomaly of the

stream flowing *towards* us, we at last reach Naukatchia Tál. Facing still to the south-east, we have on our left the lofty range separating the valley from Malwa Tál and on our right the low range on which Dhansila and Sirori are built. In front of us is Naukatchia Tál, and beyond Naukatchia Tál the valley comes to an abrupt end, and a very remarkable one.

As in the case of Bhim Tál, so in the present instance the original and natural course for the surplus waters of Naukatchia Tál would seem to be to the south straight into the Gola river, a distance of but a little over 6 miles, instead of which they reach the Gola by a circuitous course of 16 miles, the first 4 of which seem a reversal, as far as direction goes, of the original drainage of the valley. The main obstruction, looking across the lake in a south-east direction, is a low hill, somewhat centrically situated, and which is evidently composed of rock *in situ*. On the left this hill is united with the Mahragaon range by sloping ground, much masked by detritus from the heights above, along which the road from Bhim Tál to Malwa Tál is carried. Here, too, I think, there is little doubt that the valley is closed to a higher level than the lake, by rock *in situ*. On the right hand side, however, of the central hill, such does not appear to be the case, and on this side would seem to be the original and natural outlet of the lake, or of the valley prior to the conversion of part of it into a lake. The only obstacle here interposed between the waters of the lake and a precipitous valley leading straight down into the Gola river, is what I may designate as a causeway, wherein I could detect no rock *in situ*, and which resembles nothing more than a railway embankment connecting the central hill with the opposite or south-west side of the valley. This bank which might be (not that I wish to infer that it is of artificial origin) is not 50 feet broad at the top and forms the watershed between Naukatchia Tál at its immediate foot on one side and a sheer descent into the Gola river on the other; it has no appearance of a 'landslip' and any slip from the central hill would take place rather to the south-east which is its precipitous side than to the south-west where this bank connects it with the high ground opposite. The waters of the lake actually rest against this bank, without any intermediate catchment area in that quarter, and yet the lake is a deep one. If, then, this bank is not a 'landslip,' there seems no resource left but to regard it as a moraine, which crossed the valley at right angles from the heights behind Mahragaon, thereby creating the lake by obstructing the drainage. Every collateral consideration favours this view. In the first place, we must remember that there is every reason to suppose (as remarked by Mr. Ball) that the original course of the stream (and in my view, of the glacier subsequently) through Bhim Tál was out and through its extreme southern end. Then the ground between Bhim Tál and Naukatchia Tál is so open and level as to suggest the possibility of its having been once continuously covered by a lake embracing in its limits both the existing lakes, and that the spot below Dhansila, where the escape waters from both lakes meet, was originally a low water-parting between them. On the supposition that the lakes were once united, this reversal of conditions is easily understood. The lakes being both simultaneously and similarly blocked at their natural outlet to the south, continued to rise and

spread, till their united waters discovered the weakest part of the barriers enclosing them. This was at Dhansila, which at once became the point of discharge for their joint waters, the constant cutting action of which has resulted in the features the ground now displays. Whilst then the glacier of Bhim Tál was descending west of Dhansila, the glaciers descending from the heights between Mahragaon (behind Naukatchia Tál) and Padani, were pushing straight across the ground immediately below them, with the result that the Padani glacier cut through the trap ridge, and initiated the channel by which the waters of both lakes *now* escape, whilst the Mahragaon[1] glacier pursued a parallel course west of Sitalahat, its 'moraines' serving to impound the drainage between Padani and Mahragaon, thereby creating Naukatchia Tál.

The point of supreme interest of course is, why a circuitous exit across a hard trap ridge should have been selected by the waters of both lakes in preference to a more direct and undeniably natural course across the apparently weaker obstacle of a landslip or 'boulder bed.' As regards a boulder bed initiating a lake, I may observe that every Himalayan gorge is full of boulders, but in no instance do they give rise to lakes. A flood may throw a bar of them across the channel, but the next flood makes a clean sweep of the obstruction. Of course the 'boulder bed' which could be presumed to have given rise to the lake could not have itself originated therein, and besides the Kumaun lakes, from their limited dimensions and sheltered situation, do not produce *boulders*, being very different from those grand Italian lakes

"*Tu Lari maxime, tuque*
Fluctibus et fremitu assurgens, Benace, marino,"

and in the deepest of them, Naukatchia Tál, the sides may be seen dipping down at a steep angle and composed of angular fragments evidently never disturbed by wave motion. The result of my own examination of the point of exit of the joint waters below Dhansila was very instructive. At Dhansila there is no doubt of the ridge whereon it stands being composed of rock *in situ*, but across the gorge through which the stream passes, that is, exactly south-east of Dhansila, I could detect no rock *in situ*. The entire ground is covered with loose subangular masses of hard trap, up to even 100 feet girth, but no rock *in situ* could I detect after a careful search. There are some rocks of course which from their composition decompose so freely at the surface, that it is not easy to find a clean natural section or exposure of them; but such is not the character of the harsh intractable trap of Malwa Tál and the neighbourhood, such as formed the bulk of all the fragments here strewed about. To me the conclusion was overwhelming, that I was on the 'moraine' of an old glacier which had wound past Dhansila, and along whose channel the escape waters of the two lakes had made their passage.

The ice work of the old glacier, sawing its way across the obstructive ridge at Dhansila, renders it easy to understand how the waters of both lakes, on their natural point of discharge being blocked, came to select this point as the

[1] That above Naukatchia Tál, not the village of the same name, north of Bhim Tál.

easiest for their new course, and such I believe to be the true explanation of an otherwise puzzling phenomenon.

The only thing to be said against it is, that it must stand or fall with the glacial hypothesis of the origin of the lakes.

Naini Tál.

My notes on this lake need only be brief, as I have already noticed the chief points wherein I differ from Mr. Ball respecting it. The most important remark I have to make is regarding what remains of the old Naini moraine. Of course I regard the barrier as virtually composed of old moraine materials; but immediately below the 'barrier' the 'moraine' has been engulphed in the steep gorge, down which the escape waters of the lake precipitate themselves in their course to the Balia river. If, however, leaving the 'outfall' of the lake, we go along the cart-road, till we come in sight of the Brewery (*Sharáb-batti* of the 1-inch map) and direct our eyes beyond it, we can see a little to the left of it (and of course below it) a small hill. This hill, in my opinion, constitutes one of the most prominent 'hummocks' of the old Naini 'moraine,' there still preserved intact, and *in situ*. The stream which below the 'outfall' of the lake has cut away and engulphed the old 'moraine' in the chasm worn by its waters, has lower down found an easier channel to the westward, and hence for some distance above and below Suria Tál, the old Naini 'moraine' still remains intact. Suria Tál is indeed merely a pool formed by the local drainage being shut up by the 'moraine' sweeping past to the south-west. The village of Gitia (which is not marked on the map, but lies west of Suria Tál) stands on the 'moraine,' and below it spreads a highly irregular, 'hummocky' surface, freckled over with monstrous angular blocks of limestone, derived from the Naini basin and constituting the actual 'body and bones' of the old 'moraine.' At least this is my idea. I confess I *did* see a difficulty once, not sufficient to outweigh the evidence afforded by the physical character of the ground, but still a difficulty, and that was, that the section displayed on the river abreast of this 'moraine' was one of ordinary river boulder gravel; very coarse no doubt, but *not* distinctly marked by the presence in it of the huge erratic masses which encumbered the surface a short distance off. I did not then know what my last season's work has placed beyond all question, that the 'moraines,' to whose action I attribute the formation of the Kumaun lakes, are far newer than the old gravels filling the valleys, and on which old gravels they may occasionally be seen to rest. I shall not here enter further on this important discovery, beyond saying that it at once disposes of the difficulty I once felt in the fact of the huge 'erratics' embedded in the 'moraines' (as I regard them) not being seen in the old gravels; but the full discussion of this question must be reserved for another paper.

Malwa Tál.

This lake, if the form of its basin is less suggestive of a glacier than is the case with either Naini Tál or Bhim Tál, is one which it is, on the other hand, more difficult to regard as due to a landslip than almost any lake in Kumaun.

It lies in the direct course of what in the rains must be a considerable river, and though the sides of the valley are steep, they do not so materially differ in this or any other respect from other gorges in the hills as to afford an adequate explanation why a 'slip' from them of loose materials should produce a result which we cannot trace elsewhere where similar physical features prevail. I have already dwelt on the point that banks of shingle (and fallen detritus from the sides of the valley would share the same fate) do not in Himalayan streams, be they large or small, give rise to permanent lakes, and it is therefore difficult to understand how Malwa Tál comes to occupy the position it does, save on the supposition that it lies in a basin cut out of the rock by a glacier. On the descent to Malwa Tál by the road from Bhim Tál some very hard and massive trap is seen, and it appears as though a band of this rock crosses the valley just below the lake. If this supposition is correct, and if a glacier ever did descend the valley, the natural result would be the formation of a rock basin in the position now occupied by the lake, owing to the more energetic excavation effected by the glacier in the comparatively softer rocks above than on the hard band of rocks which may be considered as forming the lake sill at its point of discharge. It is true Mr. Ball declares no rock *in situ* is there visible, but without admitting that this fact has been satisfactorily established, or can be by a mere superficial examination, I would suggest that, considering the steepness of the sides of the valley, we may not unnaturally expect to find the bottom covered with a considerable amount of loose debris, quite sufficient to conceal any exposure of rock at the surface.

From different aspects, therefore, do the three chief lakes of Kumaun—Malwa Tál on the one hand and Naini Tál and Bhim Tál on the other—give strong countenance to the idea that they one and all originate from glacial agency.

Khurpa Tál.

This lake, which every traveller to Naini Tál from Káladungi must have remarked after turning the corner of the spur which descends from Deoputhar peak, is a little cocked-hat sort of depression, immediately below the road, encircled by rather steep sides, and with no visible outlet. Its natural outlet should be at its northern end, and percolation through a barrier of loose stony materials in that quarter no doubt suffices to carry off its surplus waters. But what is the nature of this barrier? The choice avowedly lies between Mr. Ball's theory of lake formation in these hills by "landslips" and mine by "moraines." It is to be regretted that Mr. Ball does not seem to have examined this lake, since it is one which, in my opinion, places the "landslip" theory entirely 'out of court.' In the case of Khurpa Tál the only direction whence the materials of the barrier almost encircling it could have been derived by a slip is from the abrupt flanks of the Deoputhar spur to the north-west. But the lake itself nestles at the foot of the spur and occupies the position of the hypotenuse of the slope which such a fall of materials would have created, and I need hardly point out, that no forces of nature could create a lake in such a position, that is, on the slope or hypotenuse of a mass of fallen rock. Regarding the 'barrier,' however, as a 'moraine,' no difficulty is

encountered. The glacier which brought down the 'moraine' in question, descended in a southerly direction from the peak of 7,989 feet, standing at the head of the Naini basin, and from the opposite side from that whence the Naini glacier itself descended. The valley traversed by this glacier (and along which the road to Naini from Káladungi winds) is towards its head blocked, or encumbered with a confused mass of angular blocks, which in part at least represents the old 'moraine,' though the Deoputhar ridge and the Iarputhar ridge on the opposite side are both so steep that avalanches and landslips may have largely added to its original mass. The progressive movement, however, of the bulk of this mass can, I think, only have been effected by ice, as the blocks composing it are so large and angular, the slope so high, and the surface so incapable of generating a large stream, from the water sinking engulphed in the interstices between the blocks, that fluviatile action is impossible. Some halfway down the valley, this mass, which I designate a moraine, terminates in a steep bluff, precisely resembling on a large scale an unfinished railway embankment, and below this lies the unnamed lake (or lakes, for the map shows two), across the outlet sluice of which the road is carried towards Naini after passing Khurpa Tál. Below this outlet sluice the valley rapidly falls (the moraine being here probably engulphed in precisely the same fashion as is the case below the Naini outfall), till past the old iron furnace, which stands nearly in its path, when the usual and characteristic components of a moraine are met with in profusion all round the spot on which the large bungalow, beyond the furnace, is built; and it is this moraine which intercepts a small portion of the drainage from the Deoputhar spur, and thereby gives rise to the little cocked-hat, dignified by the name of Khurpa Tál, but the interest and value of which as bearing on the origin of the Kumaun lakes is in inverse ratio to its tiny dimensions. There is one point, perhaps, which calls for notice in connection with the above small unnamed lakes, and that is, that they lie directly in the path as it were of the above 'moraine' (as I regard it, which I have described as terminating in a steep bluff) and occupy an intermediate space, comparatively free from large blocks between the moraine above them, and the similar heterogenous assemblage of rocky materials, met with lower down around Khurpa Tál. The reason is, in my opinion, not far to seek if we reflect on the conditions under which such a 'moraine' was formed in so rocky and precipitous a gorge as that east of the Deoputhar ridge. A 'moraine' is made up in varying proportions, according to the character of the rocks, of materials projected on to it in a more or less irregular fashion from both sides of the gorge or valley down which it is slowly progressing, and comparatively bald places may be left on it, wherein few or no large blocks may be found. The same aspect of the surface may also be induced by the filling up of irregular dips therein by ordinary rainwash, the silting up of all interstices between the larger blocks being the probable cause of the small unnamed lakes in question.

Sáth Tál.

The group of Sáth Tál, or seven lakes, as the name implies, is represented on the map by but three—namely, a small one to the north, a large one to the south,

evidently compounded of two or more contiguous basins united, and a minute lake to the west. As in the case of Bhim Tál and Naukatchia Tál the drainage of these lakes can only be indistinctly made out from the map. The small lake to the west is the lowest, and the drainage from the other lakes is passed through it. It is mainly remarkable, as affording a complete disproof of the notion of any overpowering rush of water, being the agent whereby the large blocks seen in the barrier of the large lake just above it were brought down to their present position, as any such rush of water so laden with stones and mud must have simply obliterated this little hollow, as easily as a man's thumb wipes out a spot of ink. The barrier below it is of large rough stones, fallen mainly from the hills adjoining it, which are so permeable that they do not allow its waters to ever stand for long at a high level; but although thus permeable to clear, or moderately turbid water, anything like a moving flood of mud capable of bringing down enormous masses of rock, must have filled up the lake flush with its barrier, and then passed onwards down the gorge. But this obliteration of the tiny basin has not occurred, therefore no such floods can have ever passed over it.

The uppermost lake to the north is a little cocked-hat of a lake with steep sides of loose materials, and without visible outlet, in this respect resembling Khurpa Tál. Its surplus waters, however, find an exit by percolation through the barrier (moraine) separating it from the larger lake, whose surplus waters they join below the barrier. The larger lake is created by the obstruction caused by the above barrier. This barrier is a huge bank of earth and stones, some of the embedded blocks of rocks measuring 30 or 40 feet in girth. This mass of materials, which I cannot but regard as a 'moraine,' has crept down from almost due north, till arrested by the hill whereon Siloti stands. The impounded drainage from the eastward has consequently gathered into the form of a lake of very irregular shape, the escape waters from which have scoured a passage for themselves, between the termination of the moraine and the mountain side, whereon it abuts, and whereby it became arrested and deflected to the west from its north and south course. It is an objection in the mind of some, who are opposed to the idea of ice action, that the ultimate source or head of this moraine is not quite a mile off. This, so far from being a valid obstacle to the view adopted by me, is probably, as I shall endeavour soon to show, the main cause of the very existence now of the lake, and moreover such objectors should reflect that if a limited catchment area is opposed to the genesis of a large moraine, *a fortiori* is it incapable of giving birth to a stream adequate to transporting such blocks as help to form the barrier in question.

CONCLUDING REMARKS.

Having attempted in the previous pages to establish a case in favour of the idea that glaciers have been the proximate agents in the formation of the lakes of Kumaun, if not by the actual excavation of a rock basin in all cases, at least by the obstruction, caused on their retrocession, by the large accumulations of 'moraine' matter abandoned in their wake, I would offer a few words touching some objections which may be urged against my views.

It will not be contended, I think, and certainly not by myself, that the Kumaun district is distinguished *cæteris paribus*, as regards climate or as regards any occult orographical features, from any similar and corresponding area of the Himalayan region in general. If, then, the Kumaun lakes are due to glaciers, and if (as I hold) similar glacial conditions extended far and wide beyond the limits of Kumaun, how comes it, it may not impertinently be asked, that the entire Himalayan region is not similarly dotted over with lakes, large and small, as in a part of Kumaun? How comes a cause, exercised over so wide an area, to be attested by results confined within such narrow limits? For my part I frankly accept the first deduction, and believe that the entire Himalayan region was once dotted over with lakes, originating in the same causes and in the same manner as those of Kumaun, but from the physical or petrological character of the rocks in the vicinage of the Kumaun lakes they have remained (or many of them), whilst the great majority of the lakes of contemporary origin over the entire Himalayan region have disappeared under the operation of ordinary denudational forces. Malwa Tál illustrates, in my opinion, the process in question. It is one of the largest lakes in Kumaun, and possesses out of all comparison the largest catchment. Under any circumstances of origin, we might therefore expect a barrier of corresponding dimensions. But 'barrier' there is none save the artificial sluice wall. True, one may potter about the outfall without detecting rock *in situ*, but there is nothing analogous to the mole-like mass which constitutes the 'barriers' of the other lakes. Doubtless the reason is, the flood waters of its large catchment area have swept the whole away, and the lake owes its continued existence to the fact of its having been endowed with not only a barrier, but a true rock basin likewise. The one has disappeared, the other remains. This, it may be alleged, is mere supposition, but it is not unwarranted, I think, by the circumstances, for other *raison d' être* for this lake save a rock basin, I can imagine none.

The hard limestones, traps, and trap-like schists, of this part of Kumaun readily break up into a confused heap of fragments of all sizes, and the fragments heaped together (as I argue in the shape of moraines) form an obstacle, practically, in most cases, unassailable by the slender supply of water passed over them. In such a case as Malwa Tál with its large catchment area, the 'barrier' does go. In Naini Tál and perhaps other instances, the said 'barrier' becomes attacked in places, and undercut and partially engulphed in the chasm formed by the stream, which is wholly powerless to remove it in any more direct fashion, whilst in the smaller lakes, with no catchment area to speak of, beyond their sloping sides, we see the pent up waters finding their way out by percolation, through the loose materials which surround them.

I doubt not moreover that an additional argument and illustration of the view here set forth will be found when the lakes high up on the frontier of Northern Hazára come to be examined. These, too, clearly have very small catchment areas, to which, as in Kumaun, their survival is probably due, but political considerations at present stand in the way of a European spending much time in the neighbourhood of the independent hill tribes in that quarter.

ON THE DISCOVERY OF A CELT OF PALÆOLITHIC TYPE IN THE PUNJAB, *by* W. THEOBALD, *Geological Survey of India.*

The celt, to which this notice refers, is interesting, as being the first specimen of these articles yet discovered in the Punjab, so far as I am aware. 'Chips' and 'scrapers,' and remarkably fine 'cores' of chert, have been found in Sind, but no larger implements. The present celt is composed of a pale homogenous limestone, probably of nummulitic age, and presents a surface much corroded by exposure to the atmosphere, the stone of which it is composed being evidently of a character to suffer materially from such exposure. The shape, however, of the article and the peculiar sinuous edge, the result of chipping from alternate sides, leaves no doubt as to its artificial character. It is, however, so rudely formed, that many similar specimens might escape observation, save to the practised eye of one familiar with such objects, and it is hoped that the present notice of this 'find' may result in the discovery of other specimens. It was picked up by myself on February 21st, 1879, on the surface of the ground, exactly opposite the village of Shodipur, on the Indus, 25 miles as the crow flies in a south-west direction below Attock. On showing the specimen to Kishen Singh, of the Geological Survey, he informed me he had once picked up a similar article near Rhotas, but being in doubt as to its character, had thrown it away again. This was unfortunate, but I mention the circumstance to direct the attention of future observers to the probable occurrence of these articles in other parts of the Punjab.

PALÆONTOLOGICAL NOTES FROM THE KARHARBARI AND SOUTH REWAH COAL-FIELDS, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

At end of last March and beginning of April, I had an opportunity of re-visiting the Karharbári coal-field, and, thanks to the kindness of Mr. W. G. Olpherts, C.E., F.G.S., the present manager of the East Indian Railway Company's Collieries, and to the assistance of Mr. N. Miller, Inspector at Passerabhia, I could collect further information regarding the comparison of the seams and the flora at the various places, supplementary to the views advanced in my Talchir-Karharbári flora.[1] I had the good fortune to collect numerous fossils from the second seam, from which none were hitherto known. As will be seen hereafter, this flora differs to a certain extent from that of the lower seam, and it would therefore appear that, although the parting between the second and the bottom seam is only thin, they have to be considered as distinct. I also obtained specimens from the other seams, so it will be well to say a few words about each of them. I shall do so in ascending order.

1. *No.* 1 *seam—bottom seam.*

Fossils from this coal seam are enumerated in my flora from eight places,

[1] Pal. Indica, Ser. XII, pt. 1, 1879.

three in the Serampur area,[1] and five in the Karharbári area[2] of the field. They come out of the shales in the roof of the seam.

It is this seam which has the greatest number of the peculiar fossils, and is most closely connected with the Talchir group. Of the common Damuda fossils we find *Glossopteris*, only rarely, and of *Vertebraria*, only two very small fragments were met with at one locality, No. 5D shaft, Passerabhia.

During my recent visit to the field, I did not collect many fossils from the bottom seam, but I happened to discover, amongst other rock specimens lying at the manager's office at Giridi, two nice specimens of fossils which Mr. Olpherts was kind enough to present to our Museum.

One of the specimens is from the bottom seam (No. 5D shaft) at Passerabhia (Karharbári), the other from the same seam (No. 11A shaft) at Buriadi (Serampur).

I also secured other duplicate fossils from these two shafts.

There are amongst them—

Neuropteris valida, Fstm., from both shafts.

Nöggerathiopsis hislopi, Fstm., also from both shafts.

Of this latter the two specimens presented by Mr. Olpherts are very large leaves, the largest we at present know from India; they will be figured in a supplemental fasciculus to the Talchir-Karharbári flora of the Palæontologia Indica; the specimen from Buriadi is almost complete, the basal portion only being broken off, while the apical portion is perfect. The Passerabhia specimen is although almost as large as the former, not so complete, a good deal of the apical portion being wanting; it shows, however, quite well the characters of the species, and must originally have been of a very large size.

The sections of these two shafts, showing the position of the fossiliferous shale, have been given in my Talchir-Karharbári flora,[3] to which I now refer.

I have picked up a few fossils at a new locality, No. 5 shaft, Jogitand, which also works the bottom seam. I give the section in descending order[4]:—

No. 5 shaft, Jogitand.

Soil	1′		
Sandy brown clay	38′		
Sandstone	18′		
Strong dark shale	5′	9″	
Sandstone	47′	3″	
Strong dark shale with bands of coal (includes representative of 2nd seam)	5′	3″	[Fossils from the base of this band.
No. 1 seam: coal	12′		
Total	127′	3″	

[1] Buriadi (11A); Chunka (Nos. 16 and 16G shafts).

[2] Passerabhia (Nos. 5D and 5G shafts); Mathadi (No. 1); Jogitand (No. 2) Domanighât.

[3] Pal. Indica, Ser. XII, pt. 1, pp. 36, 39.

[4] This and the two following sections were kindly supplied by Mr. W. G. Olpherts.

The fossils found represent, however, one species only:—

Nöggerathiopsis hislopi, Fstm.

The position of the fossiliferons band is the same as in No. 2 shaft Jogitand (*l. c.* pp. 42, 43); three species were named from this latter shaft, which are those of the bottom seam elsewhere.

We now know, therefore, fossils from the bottom seam from the following places:—

Karharbári area.	Passerabhia, shafts No. 5D, No. 5G; Máthadi, shaft No. 1; Jogitand, shafts No. 2, No. 5; Domahni ghat.
Serampur area.	Buriadi, shaft No. 11A; Chunka, shafts No. 16 and No. 16G.

The thicknesses of the bottom seam at the respective places are—

11′ (including 3′ partings), 11′ (including 3′ partings), 13′, 8′, 12′, 9′, 14′, 9′, 12′ 6″.

The coal belongs to the lowest hitherto known in India, and owes perhaps to this circumstance its superior quality.

No. 2 seam.

Already in my Flora of the Talchir-Karharbári beds (*l. c.* pp. 39, 40) when quoting the sections of shafts Nos. 5D and 5G (Passerabhia), I indicated the existence of a second seam above the bottom seam, separated from this latter at both places by a 2′ 6″ parting of laminated sandstones and shales, in which the fossils of the bottom seam were found; the coal measured 7′ 2″ and 7′ respectively; both seams are worked together at these places.

At Jogitand this second seam is much thinner, being 2′ 6″ in No. 2 shaft, and being represented by dark shale in No. 5; the parting of black shale at No. 2 is 2′ 5″ thick.

At Máthadi the second seam is represented by only very thin bands of coal, separated by 6′ 7″ sandstone and shale from the bottom seam. At Domahni ghât are two outcrops of coal, one of which is the second seam; in the Serampur area there is also another seam close above the bottom seam which measures at Buriadi (shaft 11A) 2′ 6″, at Chunka (shaft 16) 7′ 6″, and (shaft 16 G) 6′, being separated from the bottom seam by 3′ 3″, 12′ 6″, and 6′ 6″ sandstone and shale partings, from which latter the fossils were procured, by which the lower seam here was correlated with the same in the Karharbári area.

No fossils were up till lately known from the layers above the second seam, the reason of which certainly lies in the overlying rock at the places mentioned consisting of sandstone only, which is very badly adapted for preservation of plants.

During my recent visit, however, I just came in time to collect fossils at two pits which work the second seam separately, the bottom seam being not reached yet, or not cut through, so that I am now able, for the first time, to introduce fossils from the second seam; the two shafts are in the Karharbári area, at Passerabhia, and their numbers are, No. 24 (29 new) and No. 40 (33

new). I shall name the fossils from each separately, quoting also the sections of the shafts to show the position of the fossiliferous band.

No. 24 (29 new) shaft, Passerabhia.

	Section.		
	Soil and brickwork	31′ 4″	
	Sandstone	114′ 1″	
	Coal	1′ 9″	
	Sandstone	2′ 4″	
	Coal	2′ 8″	
	Sandstone	15′ 6″	
	Coal	1′	
	Sandstone	7′ 8″	
	Shale	7″	Fossils found in this band.
3RD SEAM	*Coal*	1′ 8″	
3RD SEAM	Carbonaceous shale	2″	
3RD SEAM	Coal	9″	
3RD SEAM	Soft, laminated bright coal	2″	
3RD SEAM	Coal	3′ 4″	
3RD SEAM	Carbonaceous shale	5″	
3RD SEAM	Burnt coal (by trap)	1′ 7″	
	Bottom seam not reached.		
	TOTAL	184′ 7″	

The thickness of the seam is therefore 7′ 8″, with 7″ partings of shale, which corresponds well with the thickness of the second seam in the sections of shafts Nos. 5D and 5G[1] (Passerabhia).

The fossiliferous band in the present shaft is the 7″ shale above the coal.

It is very dark grey, very close, shale crowded with fossil leaves, which partly are in so close layers that it is difficult to get an entire leaf.

The fossils are—

Glossopteris communis, Fstm. Very numerous.
Gangamopteris cyclopteroides, Fstm.
Nöggerathiopsis hislopi, Fstm. Rare.

Shaft No. 40 (33 new), Passerabhia.[2]

	Section.	
3RD SEAM	Soil and brickwork	9′ 6″
3RD SEAM	Sandstone	18′ 3″
3RD SEAM	Coal	7′ 11″
3RD SEAM	Sandstone	19′ 4″
3RD SEAM	Shale	1′ 2″
3RD SEAM	Sandstone	82′ 1″
	Carried over	138′ 3″

[1] Pal. Indica, Ser. XII, pt. 1, 1879, pp. 39, 40.

[2] This section is also otherwise of interest, showing the position of all the three seams of this area.

	Brought forward	138′ 3″
	Dark sandstone	4′ 11″
	Sandstone	11′ 10″
	Stony coal	2′ 3″
	Sandstone	10′ 9′
	Stony coal	6″
	Sandstone	17′ 1″
	Shale (fossiliferous)	10″
2ND SEAM	*Coal*	1′ 10″
	Carbonaceous shale	2″
	Coal	1′ 1″
	Burnt *Coal*	4′
	Trap	1″
	Charred *Coal*	1′ 1″
	Sandstone	11″
	Carbonaceous shale	2′ 7″
	Sandstone	10″
	Shale	4″
1ST SEAM	Bottom seam, stony and burnt (Seam not cut through)	3′
	TOTAL	202′ 4″

The fossils at this locality were more various, and are preserved partly in a dark fine, grained shale, and partly in a more sandy rock. They are—

Schizoneura ? (probably ? *gondwanensis*)—two specimens, rather badly preserved, but showing apparently an arrangement of leaflets like in *Schizoneura*, with dissolved sheaths.

Equisetaceous stalks. These are very numerous, and all of the same kind, *i.e.*, very broadly ribbed, ribs and furrows in juxta-position. They are presumably the stalks and stems of the same plant, to which the above-mentioned leaved specimens belong, probably *Schizoneura*.

Vertebraria indica, Royle.—Several specimens of the real Damuda form ; also branched specimens.

Gangamopteris cyclopteroides, Fstm.—The common form.

Glossopteris communis, Fstm.—Several specimens.

Glossopteris sp.—A more oval leaf, with comparatively a very long stalk.

Nöggerathiopsis hislopi, Fstm.—Several specimens, both in the dark shale and in the more sandy variety.

Seeds.—Small, slightly winged, belonging perhaps to *Nöggerathiopsis*.

Taking now these fossils and those from No. 24 into close consideration, we find that although the second seam is separated from the bottom seam by a comparatively thin band only, yet the flora has a slightly different character. *Vertebraria* becomes more numerous, and *Glossopteris*, although representing only

one or two species, occurs in greater numbers. Two not very favourably preserved specimens appear to represent *Schizoneura gondwanensis*, Fstm.

No fossils were found as yet from the seam above the bottom seam in the Serampur area, but the correlation of the second seam in the Karharbári area, with that in the Serampur area, is apparently correct, the bottom seams in both areas being the same.

The 3rd seam, Passerabhia.

There is not much new to be reported from the 3rd seam area (*l. c.* p. 40). I have obtained a few specimens from shaft No. 17 B[1] which represent a species already known from this place, *viz.*, *Nöggerathiopsis hislopi*, Bunb.; some specimens indicating very large leaves.

From shaft No. 17 C I have obtained one specimen which contains three forms new for this place and therefore for the 3rd seam.

Gangamopteris comp. *angustifolia*, Mc'Coy.—One leaf.

Winged seeds.—Of the same kind as that one figured by me from Buriadi[2] and known also from Mohpáni. Similar seeds, but smaller, are also known from the Damuda and Panchet division. I take them to represent the genus *Samaropsis* (comp *parvula*, Heer and Schmalhausen).

Seed.—Another large seed also was found. Of this I can form no idea at present, but I shall figure it with all the other new forms in a supplement to the Talchir-Karharbári flora.

This third seam appears to be developed in the northern portion of the Karharbári area only.

No. 4 seam, the "hill-seam."

In my already-mentioned paper I also mentioned the seams on the Komaljore and Bhuddua hills, classing them as a 4th seam, and judging from some fossils found on the Komaljore (Lumki) hill, and from the very much higher position of the seam, I represented them as belonging most probably to the Damuda division. No fossils were known from the Bhuddua hill. This time, however, I collected some fragments from above the coal; they are *Glossopteris*; they are of course at present quite insufficient for any conclusive decision, but I think there are stratigraphical points enough which, in combination with the fossils from the Lumki hill, show that it is an independent seam.

Bali hill in the western portion of the field is another place where this "hill seam" is represented. I have not yet examined this locality, but intend to do so on the first opportunity, as it is probable that more fossils may be found there, from which the horizon may be better fixed.

[1] The sections of this shaft, as well as of the other one, No. 17 C, are described in my Talchir-Karharbári flora, *l. c.* p. 40-42, where I also named the fossils.

[2] Ibidem, Plate XXIV, fig. 5.

The relations of the various seams may be shown in the following tabular list:—

DIVISION.	Number of seam.	Western portion.	Karharbári portion.	Serampur portion.	FOSSILS.
Damuda Division.	4th	"Hill seam" on Bali Hill.	"Hill seam" on Bhuddua; fragments of fossils (*Glossopteris.*)	"Hill seam" on Lumki Hill; a few fossils.	Named in my Talchir Karharbári Flora, p. 44. *Sphenopteris polymorpha*, Fstm. worthy of notice. Barákars.
		?	About 200′ sandstone down to the next seam.	?	
Talchir Division.	3rd	The outcrop of seams at ·)purdaha, Lopsadih and ~atighat, in Khakoo River.	3rd Seam at Passerabhia No. 17B and 17C shafts.		Named l. c., same page. Besides: *Gangamopteris angustifolia*, Mc'Coy. *Samaropsis* comp. *parvula* Heer, seed. Karharbári beds.
	2nd		2nd seam at Passerabhia (No. 24 and 40 shafts) Máthadi. Jogitand and Domahni. Fossils known from the first place.	2nd seam at Buriadi and Chunka.	Identified now for the first time:— *Schizoneura ? gondwanensis* Fstm.; *Equisetaceous* stems; *Vertebraria indica*, Royle; *Gangamopteris cyclopteroides*, Fstm. *Glossopteris communis*, Fstm.; (rather numerous) *Glossopteris* another sp., *Nöggerathiopsis hislopi*, Bunb. sp. (Feistm.); seeds. Karharbári beds.
	1st		Bottom seam at Passerabhia (No 5D, No. 53) Máthadi (No. 1) Jogitand (No. 2 and 5), Domahni.	Bottom seam at Buriadi (No. 11A). and Chunka (No. 16 and 160).	Named in the above work, p. 44. Of interest, the two large leaves of *Nöggerathiopsis*, Fstm. procured this time. Karharbári beds.

Talchir Group.

PALÆONTOLOGICAL NOTES FROM THE SOUTH REWAH COAL-FIELD.

From this extensive coal-field there were hitherto comparatively very few fossils known. Those we possessed were plants only, and belong to two collections; of the one made in 1861 by Mr. J. G. Medlicott the specimens were labeled "South Rewah" and "Sohágpur;" the former designation corresponds with what now will be distinguished as the Gopat river area, while the latter name will be retained.

Another collection, sent by Mr. C. A. Hacket, 1872, contains a few fossil

plants from the Son river, west of Garara, a place that is also represented in the collections received recently from Mr. Hughes.

From those fossils and their equivalents elsewhere I had judged that they represent the Raniganj (Kámthi) group, an opinion which the subsequent collections have confirmed.

Since October last a regular survey of this field was begun by Mr. Hughes, who has already been fortunate enough to procure a large number of interesting fossils, both vegetable and animal, which are of great importance for fixing the horizon of the beds.

Mr. Hughes has sent two collections; the first contained plants from the Lower and animals from the Upper Gondwánas. The former I was able to include in the list of localities in my paper (now in the press) on the Damuda-Panchet flora[1]; they all were of the Raniganj (Kámthi) horizon, while the animal remains were of the Maleri horizon of the Central Provinces.

The second collection contained Lower and Upper Gondwána plants, many of great interest; it arrived too late to enable me to insert the localities of Lower Gondwána fossils in the alphabetical list in my detailed work.

This collection was much larger, and contained fossils from many more horizons, also several new species of plants. In anticipation of full description and illustration I may now give a brief notice of them, so far as they are known with certainty. I shall enumerate them according to the horizons, and within each horizon from each locality. The horizons I have put down as Mr. Hughes has provisionally indicated them on his labels; two localities for which there was no horizon indicated, I have placed to such horizons as would be assigned to them by the fossils when compared with already-established classifications. I also include the older collections made by Mr. J. G. Medlicott and later by Mr. C. A. Hacket.

A.—LOWER GONDWANAS.

I. TALCHIR DIVISION.—*Talchir group.*

Goraia, on the Johilla river, near Páli, Singwara district.

Collectio Hughes, 1880.

Equisetaceous stem.—One specimen only, with a fragmentary stem, showing a fine ribbing on the surface, but no joint; may be equisetaceous.

II. DAMUDA DIVISION.

a. *Barákar group.*

Páli and *Johilla* rivers (junction of), near Páli.

Collectio Hughes, 1880.

Glossopteris communis, Fstm. Of the usual type.

Gangamopteris cyclopteroides, Fstm. There is one leaf which I cannot distinguish from this species.

[1] Pal. Indica, Ser. XII, pt. 2.

Nöggerathiopsis (? Rhiptozamites) *hislopi*, Bunb. sp (Fstm.) Numerous leaves of various sizes.
Seeds, small, slightly winged.

I must confess that this flora, small as it may appear, reminds me more of that of the 2nd and 3rd seams of the Karharbári coal-field (Karharbári beds) than of the typical Barákar group. When Mr. Hughes next season takes up work again, he will probably succeed in procuring a few more fossils which may decide the question; in the meantime they may remain with the Barákar group.

b. Raniganj group (and Kámthis).

With this group I include also those localities which Mr. Hughes marked Kámthis. Here also are placed the fossils collected previously by Messrs. J. G. Medlicott and C. A. Hacket. I name first the localities from the northern portion of the field, from the Gopat river area; these constitute also the lower Gondwána fossils of the first collection sent by Mr. Hughes in March 1880 Then follow those in the Sohágpur district.

a. Gopat river area.

Bajbai, 2 miles west of Gopat river, lat. 24° 4', long. 81° 57'.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Just like the same from the typical Raniganj group, Raniganj field.
Vertebraria indica, Royle. Many nice specimens.
Glossopteris communis, Fstm.
Glossopt. indica, Schimp.
Glossopt. angustifolia, Bgt.

Chanduidol, about 8 miles west-north-west of Bajbai, and about 3 miles west of Marhwás.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Typical Raniganj form.
Glossopteris formosa, n. sp. Raniganj species.

Mahán river (tributary of Gopat river), between Minarra (Mirhara) and Gaja (Ganjar), lat. 23° 57', long. 81° 58'.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Typical Raniganj form.
Glossopteris communis, Fstm.
Glossopt. angustifolia, Bgt.
Alethopteris comp. *whitbyensis*, Göpp. I have no means to distinguish this fern from the jurassic species.
Angiopteridium.—Two fragments of a *tæniopteroid* fern resembling a similar one in the Kámthi beds of the Nágpur area, which I quoted as *Angiopt.* comp. *mc'clellandi* O. M.

Mahán river, near Minarra (close to the former locality).

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Typical Raniganj form.
Glossopteris communis, Fstm.
Glossopt. indica, Schimp.
Glossopt. retifera, Fstm. Raniganj form.
Glossopt. angustifolia, Bgt.
Alethopteris comp. *whitbyensis*, Göpp. As above.

Mahán river, near Tansar, close to junction with Gopat river, north of the preceding locality.

Collectio Hughes, 1880.

Vertebraria indica, Royle.
Glossopteris sp.

Parasi, west of,—from stream running between Parasi and Kunjwar, about 5 miles east of Gopat river, lat. 24° 2″, long. 82° 7″.

Collectio Hughes, 1880.

Glossopteris, sp. Fragments.

With this area also those fossils contained in our collections have to be included which were collected by Mr. J. G. Medlicott, 1861, and are labelled "South Rewah." The fossils are—

Vertebraria indica, Royle.
Stems.
Glossopteris communis, Fstm.
Nöggerathiopsis hislopi. Bunb. sp. (Fstm.).
Voltzia heterophylla, Bgt. The determination of this species from this coal-field is now confirmed by Mr. Hughes' recent specimens.
Small seeds.

These fossils, however, correspond very much with those of the next following locality, in the Sohágpur district.

β. Sohágpur District.

Hardi, near—about 15 miles south-east-south of Sohágpur, long. 81° 30″, lat. 23° 6″.

Collectio Hughes, 1880.

Vertebraria indica, Royle.
Glossopteris communis, Fstm.
Nöggerathiopsis hislopi, Bunb. sp. (Fstm).
Voltzia heterophylla, Bgt. Several leaved branchlets, which leave no doubt about this species.
Samaropsis comp. *parvula*, Heer. Winged seeds, known also from other places.

Kachodhar, about 11 miles west of Sohágpur.

Collectio Hughes, 1880.

Glossopteris communis, Fstm. One leaf peculiarly folded.

Sohágpur, in South Rewah.

Collectio J. G. Medlicott, 1861.

Vertebraria indica, Royle.
Glossopteris communis, Fstm.
Glossopteris browniana, Bgt.
Glossopt. damudica, Fstm.

Son river, west of Garara, Sohágpur district.

Collectio Hacket, 1872.

Fossils in a dark greenish-grey sandy shale. Considering the fossils, I placed this locality with the Raniganj (Kámthi) group, which now by Mr. Hughes' fossils from the same locality (see next locality) is further confirmed.

The fossils were—

Vertebraria indica, Royle.
Macrotaeniopteris feddeni, Fstm. Like the same in the Kámthis of the Nágpur area.
Glossopteris communis, Fstm.
Dictyopteridium (?) sp.

Son river, near Gúrárú (as written by Mr. Hughes—Gururu on the Indian Atlas) about 1 mile east of Son river, long. 81° 23″, lat. 23° 28″.

Collectio Hughes, 1880.

This is evidently the same locality as that above mentioned of Mr. Hacket. Mr. Hughes' fossils are in two kinds of shale, one dark greenish-grey sandy, like in Mr. Hacket's specimens; the other light yellowish-grey soft clay-shale.

a.—Dark greenish-grey shale—

Schizoneura gondwanensis, Fstm. Raniganj type.
Glossopteris communis, Fstm.
Glossopt. indica, Schimp.
Squama gymnospermarum.

These fossils leave no doubt about the Raniganj horizon of this bed, as determined already before by me from Mr. Hacket's specimens.

b.—Light yellowish-grey shale.

Glossopteris angustiofolia, Bgt.
Rhipidopsis, n. sp., like in the Kámthis on the South Godávari (Kunlacheru, originally a genus in the Russian Jura of the Petschora country).

Son river, opposite Sarsi.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Very big leaves (or, better said, portions of the leaf spath.)
Glossopteris browniana, Bgt.

These fossils leave indeed no doubt as to the establishment of the typical Raniganj group in this region, as is especially illustrated by the numerous occurrence of *Schizoneura gondwanensis*, Fstm., and several species of *Glossopteris*,

occurring mostly in the Raniganj group. We can in fact say, *Schizoneura* is the characteristic feature of these localities in South Rewah, and is more widely distributed here than *Vertebraria*, as out of eleven localities, *Schizoneura* occurred in six and in great numbers, while *Vertebraria* was found only at five localities. Of other fossils I would specially point out the following :—

Macrotæniopteris feddeni, Fstm. } both of the typical Raniganj
Glossopteris formosa, n. sp., *retifera*, Fstm., } group.

Alethopteris.—There are two pinnæ of an *Alethopteris* which has to be referred to the group of *Al. whitbyensis*, Göpp. A fragment of an *Angiopteridium* has to be referred to *Ang. mc'Clellandi.*

Voltzia heterophylla, Bgt., which we already know from the Karharbári beds, is here again represented in the Raniganj group, and not rare.

c. Supra-Damudas.

On the labels of several fossils from two localities Mr. Hughes has indicated the horizon as "Supra-Damudas." To judge, however, from the fossils and from petrographical character of the specimens, the fossils indicate lower Gondwánas, although representing perhaps two horizons.

Daigaon, on the Johilla river, about 4 miles north-west of Páli.

Collectio Hughes, 1880.

Vertebraria indica, Royle.

According to our present knowledge, *Vertebraria* is especially typical of the Damuda division,[1] and in default of other fossils, I would consider this locality to belong to this division; it may be Raniganj (Kámthi) group.

Parsora (south tolah), near Beli, about 6 miles north-north-east of Páli.

Collectio Hughes, 1880.

The fossils from this locality are very interesting, especially one new species. They are preserved in a red-brown, highly ferruginous, micaceous shale, completely agreeing with the rock in which Mr. V. Ball's fossils from Latiahar, in the Auranga coal-field, are preserved, which as to the horizon[2] were left undecided, although Mr. Ball thought that they are probably "Mahádevas." Considering, however, the fossils, amongst which there is *Vertebraria* and *Glossopteris*, I treated this locality[3] as belonging to the Panchets, and it might be the same case with the present locality in South Rewah, and the more so as the fossils would perhaps support that view.

The fossils are—

Danæopsis.—A new species—in numerous specimens.

Of this genus there were hitherto known with certainty only two species,

[1] There are several specimens known from the Karhárbari beds of the Karharbári coal-field and also from a doubtful locality in the Auranga coal-field, which probably is Panchets, but, as a rule, it is a fossil of the Damudas.

[2] Ball, Mem. Geol. Survey of India, Vol. XV, pt. 2, p. 89.

[3] Pal. indica, Ser. XII, pt. 2, p. 9. (To be issued shortly.)

D. marantacea, Heer, from the German Keuper (Upper Trias), and *Danæopsis rajmahalensis*, Fstm., from the Rájmahál group in Bengal (Rájmahál hills). The present species differs from both. It is a much larger form than *D. rajmahalensis*, Fstm., as is especially seen from the thickness of the rhachis and the midribs of the pinnulæ; the veins also have another direction in *D. rajmahalensis*, passing out at a more acute angle from the rhachis and running straighter to the margin. *Danæopsis marantacea*, on the other hand, is again bigger than our present species, the whole frond appears much larger, the pinnulæ longer, the midribs thicker, and especially the top pinnulæ much larger. There are two specimens in Mr. Hughes' collection, showing the top pinnula, which is shorter than the other pinnulæ, while in *Dan. marantacea*, Heer, the top pinnula was equal in size to the others. I refer especially to Schimper's figure Tr. d. Pal. végét., Pl. XXXVII. The secondary veins in *Dan. marantacea* agree well with those in our present species.

But there is an important character in our present species of *Danæopsis;* the *primary rhachis* of the frond is *dichotomously forked*, as is shown distinctly by about six specimens; the pinnulæ at the beginning of the fork on the inner side being represented by lobes only. Below the furcation the pinnulæ are also only small. We shall have to take this present species as intermediate between *D. rajmahalensis*, Fstm., and *D. marantacea*, Heer, with closer relation to the latter. All other details will be given subsequently with illustrations. It will be described as *D. hughesi.*

Thinnfeldia comp. *odontopteroides*, Moor. sp. There are three fragments of fronds, with forked rhachis, which have entirely the aspect of *Thinnfeldia odontopteroides*, Moor. sp. A similar fern was already brought by Mr. Griesbach from the Panchets of the Ramkola coal-field, and this plant would be a support for the view of the locality under discussion being of the same horizon.

Neuropteridium, sp. There is a portion of a frond which appears to be single pinnate and belongs to Professor Schimper's triassic group of *Neuropteris*, distinguished as *Neuropteridium*. We know already one species from the Karharbári beds. The present one appears to be different.

Nöggerathiopsis hislopi, Bunb., sp. Portions of large leaves. This species is known from the whole Talchir and Damuda division.

This is certainly a very interesting association of forms, but it no doubt shows that this locality has to be considered as belonging to the Lower Gondwánas, probably Panchets, but *Danæopsis* would be another form helping to bridge over the break between the lower and upper Gondwánas.

B.—UPPER GONDWÁNAS.

a. MALERI BEDS.

The most important discovery made by Mr. Hughes is, I think, that of the Maleri horizon (of the Godávari basin) in South Rewah. It is undoubtedly established by numerous bones of land animals, the same as those in the Central Provinces.

Tiki, about 6 miles south of Beohari, long. 81° 25', lat. 23° 56'.

Collectio Hughes, 1880.

Parasuchus hislopi, Huxley (MSS.) represented by portions of jaws, several teeth, numerous fragments of dermal scutes, vertebræ, and other bones. They represent an animal about equal in size to that of the Maleri beds in the Central Provinces.

Hyperodapedon, sp. Jaws, apparently of the same animal as that of the Central Provinces, but three of the jaws are larger than any hitherto known from the latter place.

Unio, sp. Several specimens of a small Unio-like shell also occur.

b. JABALPUR GROUP.

There is another horizon of importance in this coal-field, as it contains besides most of the Jabalpur plants of the Sátpura basin, also others, and especially one species characteristic of, and hitherto only known from, the intermediate beds[1] of the upper Gondwánas on the south-east coast of India.

Bansa, on the Machrar river, about 6 miles south-west of Chandia.

Collectio Hughes, 1880.

Alethopteris whitbyensis, Göpp. Typical form.

Alethopteris indica, O. M. Probably only a larger variety of the former.

Alethopteris medlicottiana, Fstm. The same typical form as from near Jabalpur.

Besides these, there are three other ferns which require further examination.

Podozamites lanceolatus, L. & H. Numerous specimens.

Ptilophyllum cutchense, Moor., in dark sandy shale, resembling similar shales from the Sher and Hard rivers.

A cycadeaceous fruitleaf?

Taxites tenerrimus, Fstm., a Jabalpur group species.

Taxites planus, Fstm. At first described from the Ragavapuram shales, the Sripermatur group, and the Vemáveram shales, now here represented by several specimens, one a very fine one. I think we have to consider this species as surviving from these intermediate beds on the south-east coast into the Jabalpur group of South Rewah; it is not met with in the Jabalpur group of the Sátpura basin.

Brachyphyllum mammillare L. & H., completely the same form as in the typical Jabalpur group near Jabalpur.

Echinostrobus rhombicus, Fstm.

Araucarites cutchensis, Fstm. The same as in Cutch and the typical Jabalpur group.

Gingko, sp., a small leaf with a thin stalk.

Some other coniferous branches.

It will be very interesting to learn from Mr. Hughes' descriptions in what relation is Jabalpur group is to the Maleri beds of Tiki.

To make this list of fossils from South Rewah complete, I have still to quote

[1] Ragavapuran shales, Sripermatûr group, Vemáveram shales.

a few fossils which in 1872 were brought by Mr. Hacket. They were already mentioned, and some figured in my Jabalpur Flora[1] and referred to as from "South Rewah." I have since found a label referring to these South Rewah fossils and giving some information as to the locality.

Chandia, small nadi south of,—South Rewah, Singwara district.

Collectio Hacket, 1872.

1877. Feistmantel, Flora of the Jabalpur group, etc, Pal. Ind., IX., 2.

Alethopteris medlicottiana, Fstm., a small specimen not mentioned in my Jabalpur flora, found subsequently, will be figured together with Mr. Hughes' specimens.
Sagenopteris ? sp.,[2] Feistm., *l. c.*, p. 10, Pl. III, fig. 6.
Podozamites lanceolatus, L. & H., *l. c.*, p. 11, Pl. III, figs. 7, 8, 11, 12.
Podozamites spathulatus, Fstm., *l. c.*, p. 12, Pl. IV, figs. 11, 12.
Araucarites cutchensis, Fstm., *l. c.*, p. 16, Pl. XIV, figs. 11—13.
Echinostrobus expansus, Schimp., p. 17, Pl. XI, fig. 5.
Ech. rhombicus, Fstm., *l. c.*, p. 18, Pl. XI, figs. 6—11.

FURTHER NOTES ON THE CORRELATION OF THE GONDWÁNA FLORA WITH OTHER FLORAS by OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

Flora of the Kusnezk basin and Tunguska river, Siberia.

In a short note in the first number of this year's Records with reference to a preliminary paper of Mr. Schmalhausen on the jurassic flora of the Kusnezk basin and Tungska river, I compared the Indian (and Australian) leaves formerly known as *Nöggerathia*, but distinguished by me as *Nöggerathiopsis*, with the Siberian *Rhiptozamites* Schmalh, which also had at first been described as *Nöggerathia*. I have since received Prof. Schmalhausen's work, illustrated with sixteen plates,[3] and I would now complete my reference to his observations.

My supposition of our *Nöggerathiopsis* and the Siberian *Rhiptozamites*, Schmalh. being in closest relation is now confirmed. The size and form of the leaves and the characters of the veins is in both genera completely identical; the only difference between them being that the veins in *Rhiptozamites* are closer. This character might eventually be taken as a specifical distinction only, while yet the two genera might be identical. This of course is not necessarily of much consequence regarding the correlation of the two formations in which these genera are found; but their close generical relation (perhaps identity) is of great importance in fixing the systematical position of the one from the other.

Prof. Schmalhausen places his *Rhiptozamites*[4] (which name by itself implies the

[1] Pal. Indica, Ser. IX, pt. 2.

[2] In the paper quoted the locality of this fossil is by mistake given as Jabalpur instead of South Rewah.

[3] Beiträge zur Jura-Flora Russlands, von Joh Schmalhausen, in Mem. de l'Acad. Impér. des Sc. de St. Petersbourg VII, Ser., Tome XXVII., No. 4.

[4] ῥίπτω- to cast off, and *Zamia*—botanical name.

cycadeaceous nature) with the *Cycadeaceæ*, together with well-known cycadeaceous genera, such as *Ctenophyllum*, *Dioonites*, and *Podozamites*; in the first instance these leaves (*Rhiptozamites*) which are described as pinnate (I used for the Indian leaves the expression *foliis biserialibus*), are compared with forms of *Podozamites*, as I also had done with the Indian leaves, before Prof. Schmalhausen's paper was in my hands.[1]

The Siberian leaves are described as deciduous, being generally found as single leaves; this certainly was also the case with the Indian forms, as all the leaves hitherto found were detached (*l. c.* p. 24).

Prof. Schmalhausen also points to the unequilateral shape of the leaves, adducing this as a character in favour of the view of the fronds having been pinnate, in which case the leaves generally met with would be the pinnulæ. A similar character had already been observed in the Indian leaves from the Nágpur area by Sir Ch. Bunbury, who expressed it by saying the leaves were "not symmetrical, but very slightly oblique," and I confirmed it subsequently from the Karharbári specimens (*l. c.* p. 24 and figures); it is seen also in all the specimens from the other localities, so that we may fairly use this character in support of the view that the detached leaflets belonged to a pinnate frond. Amongst the Indian specimens not one has been observed showing the connection with the stalk; but there are several specimens (from the Raniganj field, from South Rewah, and the Sátpura basin) which show such an association of two or three leaves as forcibly reminds us of an arrangement of the pinnulæ in a pinnate leaf.

With this close generical relation (eventually identity) of *Rhiptozamites* Schmalh. and *Nöggerathiopsis*, Fstm. in view, we are completely justified in placing these latter also with the order *Cycadeaceæ*, family *Zamieæ*, and have to compare them, as I have already done, with the fossil *Podozamites*, which is essentially a mesozoic and prominently jurassic genus, known in the Upper Gondwánas in India, in the Kusnezk basis in the Altai (in association with *Rhiptozamites*), and in the jura of E. Siberia and in the Amur countries; also numerous in Europe. This cycadeaceous plant, *Nöggerathiopsis*, is rather numerous in the Lower Gondwánas; it occurs in—

THE TALCHIR DIVISION ...	Talchir group: rare (Deoghur). Karharbári beds: very numerous both in the Karharbári field (Nos. 1, 2, 3 seams) and in the Mohpáni coal-field.
DAMUDA DIVISION ...	Barákar group: Rámkola coal-field, South Rewah coal-field, Sátpura basin (Shahpur and Umrét). Raniganj (Kámthi): Raniganj coal-field (rare); South Rewah (frequent). Nágpur district (Kámthis): numerous.

This *Nöggerathiopsis* forms in the Lower Gondwánas just as prominent a feature as *Pterophyllum*, or *Cycadites*, or *Podozamites* does in the Upper Gondwánas, and consequently the great break between the Lower and Upper Gondwánas is

[1] Pal. Indica, Ser. XII, 1, p. 23.

now—as regards at least the *Cycadeaceæ*—to a great extent removed. This break is still more filled in by the interesting circumstance (to be noticed presently) that there are other forms, both in the Lower and Upper Gondwánas, which find their close analogies or identical representatives in the Jura of the Altai and Siberia and elsewhere.

Before proceeding to this point, the systematical position and analogies of *Nöggerathiopsis*, Fstm., may be therefore expressed thus—

CYCADEACEÆ.

a. ZAMIEÆ.

Nöggerathiopsis, Fstm.	*Nöggerathiopsis*, Fstm.	*Rhiptozamites*, Schmalh.	*Podozamites*, Br.
Palæozoic—Australia (N. S. Wales).	Lower Gondwánas, India.	Jura—Altai and the Tunguska River.	Jura—(Upper Gondwánas,) in India, Siberia, and elsewhere.

The jurassic flora described by Professor Schmalhausen from the Altai Mts. and the Tunguska river,[1] is further interesting, as it contains several forms partly identical with and partly closely related to species in the Upper and Lower Gondwánas of India, representing thus, so to speak, an amalgamation of parts of both. Taking also the other jurassic floras of E. Siberia and the Amur countries (Heer) into consideration, we can establish the following list of correlations :—

GONDWANA SYSTEM—INDIA.	JURA—SIBERIA, ETC.
a. UPPER GONDWANAS.	
Alethopteris whitbyensis, Göpp. Kach and Jabalpur group; Sripermatur group (Sripermatur and Vemáveram). *Alethopteris indica*, Oldh. and Morr. Sripermatur and Rájmahál group.	*Asplenium whitbyense*, Heer (Siberia and Amur countries).
Dicksonia bindrabunensis, Fstm. Rájmahál group.	*Dicksonia concinna*, Heer. Amur countries.
Podozamites lanceolatus, Schimp. Jabalpur and Sripermatur group.	*Podozamites lanceolatus*, *eichwaldi*, etc. E. Siberia and the Altai.
Anomozamites (*Pterophyllum*) *princeps*, O. M. Rájmahál group.	*Anomozamites schmidti*, Heer. Amur countries.
Anomozamites lindleyanus, Schimp. Sripermatur group.	*Anomozamites lindleyanus*, Heer. E. Siberia.
Gingko lobata, Fstm. Jabalpur group.	*Gingko digitata*, Heer. E. Siberia and Altai.
Czekanowskia ? and *Phönicopsis* ? Jabalpur group.	*Czekanowskia* and *Phönicopsis*. Heer. Altai, E. Siberia, Amur countries.
b. LOWER GONDWANAS.	
Phyllotheca indica, Bunb. Raniganj (Kámthi) group.	*Phyllotheca sibirica*, Heer, and *Phyll.* *deliquescens*, Schmalh, (Göpp. sp.). Altai and E. Siberia.
Stems of the same.	*Stems*, quite similar (*See* Schmalhausen, *l. c.* Pl. I, fig. 2). Altai.

[1] I leave the flora of the Petschora country out of comparison here, and refer to the Asiatic (Siberian) forms only.

GONDWANA SYSTEM—INDIA—*contd.*	JURA—SIBERIA, ETC.—*contd.*
Phyllotheca robusta, Fstm. Raniganj group (Rájmahál hills).	*Phyllotheca schtschurowski*, Schmalh. Altai.
Alethopteris whitbyensis, Göpp. Raniganj group. *Alethopteris lindleyana*, Royle. Raniganj group.	*Asplenium whitbyense*, Heer. (Siberia, Amur countries.)
Cyathea comp. *tchihatcheffi*, Schmalh. Barákars.	*Cyathea tchihatcheffi*, Schm., Altai.
Dicksonia hughesi, Fstm. Raniganj group.	*Dicksonia concinna*, Heer. Amur countries.
Glossopteris gangamopteris. Lower Gondwánas. (*Rubidgea*. Karoo beds, S. Africa).	*Zamiopteris glossopteroides*, Schmalh. Altai. This fern resembles strikingly (and is also by Schmalhausen compared with) *Glossopteris* in shape and distribution of veins, but has no midrib and no anastomoses. Other specimens resemble *Gangamopteris angustifolia*, but they again want the anastomoses. The most closely related genus is *Rubidgea* from the Karoo beds; there is hardly any distinguishing character, but they are not to be mistaken for my *Palæovittaria*.
Nöggerathiopsis hislopi, Fstm. Lower Gondwánas.	*Rhiptozamites göpperti*, Schmalh. Altai, Tunguska.
Samaropsis comp. *parvula*, Heer. Karharbári beds, Raniganj group (Bijori). Panchets.	*Samaropsis parvula*, Heer. Altai (See Schmalh. *l. c.*, Pl. IV, fig. 3 *b*.) E. Siberia.
Squamæ gymnospermarum. Barákars and Raniganj group.	*Squamæ gymnospermarum*. Altai, Tunguska (Pl. XV, figs. 14, 15, represent forms of the Raniganj group, while Pl. XVI, fig. 22, represents a Barákar form).

This list speaks for itself, and there is nothing surprising in it when we consider the close relations of the various groups of the Gondwána system as independently observed. We have in addition the occurrence of *Glossopteris* in the Upper Gondwánas, the representation of *Podozamites* in the Upper, by *Nöggerathiopsis* in the Lower Gondwánas, the occurrence of *Glossopteris* and *Vertebraria*, in a horizon in the Auranga coal-field, which Mr. Ball could not assign to any bed of the Lower Gondwánas, but thought it should belong to the Máhadevas (Upper Gondwánas), although I think it may represent the Panchet group, etc. There is also a fine collection of plants made by Mr. Hughes in South Rewah, which will further illustrate this intermingling of the flora just on the boundaries between the lower and upper beds of the Gondwána system.

These relations, which no doubt will find further illustration in course of the more detailed work of the Survey, show well the fitness of combining all the beds from the Talchir group up to the Jabalpur and Kách group under one collective designation, for which the name *Gondwána system* was very happily chosen.

ADDITIONAL NOTE ON THE ARTESIAN WELLS AT PONDICHERRY, *by* W. KING, *Deputy Superintendent (Madras), Geological Survey of India.*

While my paper in the last number of the Records was in press, I received some further details from Mr. Poulain, giving corrected heights and discharges of water columns in the Savana and Ŭpallem wells, which were inserted in the body of the paper, but not in the introduction. Unfortunately I misunderstood some of these corrections, as they are explained in a later letter received from Mr. Poulain, and therefore it becomes necessary to draw attention to the following errors:—

On page 113, line 33, for 'three' read 6·5; for '44' read 30.
On page 114, line 16, for 'nearly 1 foot' read 3·28 feet.
On page 120, line 21, for '44,' read 30; for 'one' read six.

These corrections are made from a later note published in the '*Travaux des Commissions Locales*' which my friend Poulain has furnished since the publication of my paper, and of the existence of which I was unaware until now. A translation of this note is now appended; it follows as number five on the 'Experiences of Mr. Poulain' given in Appendix II of my paper.

Experience at "Savana."

"The latest information given on the progress of the borings up to the 11th September left the depth at 52·68 meters and the discharge at 90 litres a minute.

"The discharge increased proportionally with the disengagement of the sands at the bottom of the ascending column. It is now at 135 litres a minute. During the working the water had a very marked yellow-ochrey colour, and it became limpid as soon as the work was stopped. The actual depth is 53 meters.

"We have verified the hydrostatic level of this source, and as the ground surrounding our well has lately been raised by the heaping up of the excavated material, we have been obliged for exactness to take the level of the old soil. This having been ascertained, the rise is 1·96 meters above the soil. The water has not lowered from this point.

"Regarding the uses to which the water of the 'Savana' well may be applied, we cannot do better than reproduce in text the official analysis given by Mr. Castaing, Chef de Service Pharmaceutique, at the requisition of the Ordonnateur:—"Depth of the well, 52·68 meters. This water is limpid, colourless, inodorous, agreeable to the taste, and fresh. It contains 26 centigrammes of saline residue to the litre, composed of earthy chlorides and sulphates. It marks 7 degrees on the 'hydrotimètre.' It boils vegetables well, dissolves soap, and does not contain any organic matter. It possesses all the requisite conditions of a potable water, and is adapted for all culinary and industrial uses. It will leave only a feeble deposit in boilers if it be allowed to settle for a short time."

"From an agricultural point of view, and in the opinion of several native cultivators, the quantity of water now furnished by the well would be sufficient

for the cultivation of 12 cawnies of rice fields, or above double this superficies for inferior (*menus*) grain.

"The sinking of the tube will be continued for some meters more or so to penetrate further into the water sheet."

Pondicherry, 30*th September* 1877.

The search for these water sources is still being prosecuted at Pondicherry and in the neighbourhood, and this has been attended with fair success; but the Government boring in the Ville Noire is now in abeyance, as it was found impossible, with the appliances at hand, to drive the tube down beyond the depth attained, namely, about 550 feet, and there has been no further rise of water. It is proposed to run down a tube of smaller diameter, when opportunity offers.

In the meantime, a new well has been started by Government in the village of Ariankúpam, at about 300 yards from the south or right bank of the river of that name, which, however, is so far a failure also, though a rising sheet of water was tapped at a comparatively slight depth.

Here the level in the surrounding wells is at 16·40 feet below surface soil, perhaps about the mean level of Ariankúp river, which is tidal.

At 32·28 feet, water rose to a height of 3·83 feet over the surface soil. This water appears to have been the purest yet obtained in this way. After three days the discharge ceased, and the water disappeared from the tube. Mr. Poulain conceived this might be attributable to accident; that the hole made by the borer was larger than the tube, and that the water had passed away between the latter and the surrounding deposits and been absorbed into permeable beds above, and on this he suggested to Government some means for meeting the mishap. The Engineer preferred to proceed with the boring and the sinking of the tube, and now a depth of 157 feet has been reached without a further water sheet having been struck.

The deposit latterly pierced is a clay or lithomarge of a reddish colour, with veins or streaks of white, such as is occasionally met with in the sandstones of Pondicherry and Cuddalore, below which, according to one account, is a conglomerate of a greyish colour and hard enough to be taken as an approach to beds of that series.

It is indeed very possible the Cuddalore sandstones may have been touched, or that the borer is close on them, it being not at all unlikely that a sub-alluvial ridge or plateau of these beds may exist at no great depth between the Ariankúp and Punear rivers, there being here a gap of rather unexplainable width in the red sandstone belt.

The general succession of beds in this boring is:—

1. Sandy soil and sands,
2. Thin band of black clay,
3. Whitish clay,

but this requires confirmation.

A private boring was put down some time ago at Mudeliarpet, a small village in the vicinity of the Colonial Gardens and the Savana filature, and a rising

these of water was tapped at 49·20 feet, which remained at nearly a foot below surface soil. The rise increased on the boring being carried deeper, and eventually stood at the level of the ground, which is, however, 1·47 feet above the surface level at Savana, that is, 10·47 feet above sea-level. The discharge is 17·6 gallons a minute, but the tube is filled with sand for more than 3 feet from the bottom, which when cleared may allow of an increased flow.

A block of wood or a tree trunk was met with embedded in the sand at 72 feet, which disappeared, however, in some unaccountable manner after being cut at with the jumper for two or three days. Mr. Poulain seems to think that it may have been carried off by the current of water at this horizon; but such freedom of motion is hardly conceivable in alluvial strata;[1] the trunk has been probably just shoved aside.

The beds traversed are:—

	Feet.
Vegetable mould	1·96
Sandy soil	31·65
Black clay	7·87
Coarse and fine sand	39·36

This succession would tie in well with the sections exposed by the Savana, Jardin d'Acclimatation, and Upallem borings, though the clay band has thinned out a good deal from what it is at the Savana well.

Another well was commenced last year in the village of Archiwakum, about 7 miles south of Pondicherry, which reached a depth of 144·32 feet, after passing through the following strata:—

	Feet.
Vegetable mould	1·64
Red sandy soil	13·12
Micaceous sand	13·12
Very hard clay of yellowish colour, streaked with veins of light green clay, with some layers of white sand	111·52
"A sort of Molasse" of reddish yellow colour	3·28
Sand[2]	

The water ascended from the later deposit to within 6·56 feet of the surface soil, the wells of the neighbourhood having their water at 13·77 feet below surface, or perhaps about sea level.

This boring is stopped for the present, as the pipe cannot be forced down any further; but a second pipe is to be inserted in this, after which better progress may be made.

The boring in Mr. Cornet's compound, which was noticed in my previous paper (*l. c.* p. 115), has been again continued with the hope of finding a sheet of better water. It is, I believe, nearer the sea than any of the other wells to the south, and a certain oscillation of the hydrostatic level of that sheet was observed

[1] Free and cavernous passages are, I fancy, only possible in hard and rocky strata, and most frequently in soluble rocks, such as limestones.

to be apparently in accord with the rise and fall of the tide; but I have received no further information on this point. As bearing on this an important fact was brought to my notice by His Grace the Duke of Buckingham in connection with the tidal observations made at Madras by Colonel Baird, which shows that there is very free percolation of fresh water into the sea on the coast there. It appears that a well or cylinder was sunk in the vicinity of the harbour works for a tidal gauge, and it was found that the water in this well became fresh in a very short space of time. This indicates a head and large supply of water which should be struck by borings of no great depth. It may be that a stratum of this kind has been tapped by all the wells, except that of the Ville Noire and in the neighbourhood of Pondicherry, the few tubes put down having offered a freer exit than that existing, not only on the sea face, but also in the beds of the rivers near the coast.

This observation at Madras implies that the flow of water shows itself at a very shallow depth, but the free percolation must be deeper than this under the Madras plain, for it is well known that at the ordinary depth to which open wells are made here, there is not free communication of their waters. For instance, in many compounds, wells have been dug at various spots, only some of which contain fresh waters. A case in point is that of Mr. Franck's compound on the Mount Road, an area of about 3 or 4 acres in which, as far as I remember, 5 wells were dug, most of which gave brackish water, so here in this small space and at a very shallow depth, are seams of permeable strata which can hardly be in free communication with each other.

SALT IN RAJPUTANA, *by* C. A. HACKET, *Geological Survey of India.*

The soil of Rajputana, over wide areas, is impregnated with salt. This is more particularly the case on the western side of the Arvali range of hills, where large quantities of salt are manufactured from the efflorescence developed on the surface, and the water in the majority of the wells is too brackish to drink, and in some places the only drinking water obtainable is from small tanks in which the rain water is collected.

The country on the eastern side of the range, north of Ajmere, is also frequently saliferous, but with the exception of a few places, like Sámbhar and Bhartpur, not nearly to so great an extent as on the western side. South of Ajmere, on the eastern side of the range, salt is not met with in any quantity.

So many descriptions of the sources and process of manufacture of the salt of Rajputana have been published, of which the most complete are those in the Gazetteer of Rajputana and the Reports on the Administration of the Inland Customs Department, that it is unnecessary for me to enter into these particulars. The object of this paper is to give a brief description of the rocks in the neighbourhood of these salt sources with reference to the possible origin of the salt.

The salt is obtained from four sources—

1st.—From the large shallow lakes, from which great quantities of the best quality of salt are obtained.

2nd.—From earth-works, or the collection of the efflorescence on the surface of the soil, re-dissolving it in pits, and allowing it to evaporate in shallow pans.

3rd.—From weak brine wells, as at Bhartpur.

4th.—From the deposits formed in old beds of rivers.

The earth-works used to be exceedingly numerous, particularly on the western side of the Arvalis, but they are now mostly abandoned. Large quantities of salt were also obtained at Pachbadra, from pits sunk in a hollow supposed to be an old bed in the Lúni river.

Under the new salt revenue regulations the works at Bhartpur are closed, but they were once extensive. In the Gazetteer of the Bhartpur State, salt figures as more than two and a half lakhs of rupees in the revenue receipts for 1873-74. The principal works were close to the west of the city, where large evaporating areas were supplied with brine drawn from wells in the open plain. The nature of the source is altogether obscure: there is no natural surface efflorescence or any other sign to indicate the salt below: rich cultivation is carried on close to the brine wells, and in other wells at a short distance off sweet water stands at about the same level. At the time of observation (December 1865) the briny water was only 20 feet from the surface, and was said to be 20 to 30 feet deep. A well then being worked was said to have been in use for 28 years, without sensible change in the quality of the water. In one unlined well the 20 feet over water level was seen to be one unbroken mass of sandy kankary clay, of the type so general in the great alluvial deposits of the plains.

At present the manufacturing operations are almost restricted to the salt lakes, the most important of which are—

Sámbhar on the borders of Jeypore and Jodhpore—
Kachor-Rewasa ... ... in Shaikhawáti.
Dídwána and Phalodi ... ... in Jodhpore.
Lonkára Sur ... ... in Bikaneer.

But as I have visited only the first three of these lakes, my remarks will be confined to them.

The Sámbhar Lake—is situated on the eastern side of the Arvali range (Indian Atlas sheet 33, S. E.). Its greatest length is about 20 miles, and the average breadth is about 5 miles. Its greatest depth, near the centre, at the end of the rains, is seldom more than 3 feet.

The Arvali range near the lake consists of several broken parallel ridges of quartzite, some of them rising to a height of 1,000 feet above the level of the plain. The ground between the ridges is not much higher than the level of the plain to the east, and is mostly covered by the blown sand.

The country east of the range, and surrounding the lake, is covered by long ridges of sand running in an east and west direction, some of them upwards

of 100 feet in height above the level of the lake; thus the northern shore of the lake near Gudha is 1,184 feet above sea level, whilst An, about 1 mile from the southern shore, is 1,262 feet, Singla, 4 miles from the southern shore, 1,292 feet, and Duri, about 6 miles east of the lake, 1,363 feet above sea level.

These ridges of sand are formed by the west wind bringing the sand through the gaps in the ridges of quartzite forming the range. The lake is merely a hollow in the sand, lower than the surrounding country, from the fact of its lying under the lee of one of these high ridges and so protected from the blown sand.

The drainage area of the lake is about 2,200 square miles.

Of the two principal streams that flow into the lake, one takes its rise about 50 miles to the north-east, and the other near Ajmere about 40 miles to the south.

As the lake becomes dry, a deposit of black mud is left at the bottom, which, when dry, contains numerous small crystals of salt. Mr. Adams, the Assistant Commissioner of Inland Customs at Sámbhar, gives the following section of a pit sunk 10 feet deep in the bottom of the lake near the low water level opposite Japog. "After penetrating through a layer of about one and a half feet in thickness of the dark greyish sand which, when covered with water, becomes the black mud of the lake, about half a foot of quicksand with brine was met with. Below this a black micaceous sand occurred, which was much decomposed on the surface, but which became gradually harder downwards. A very similar stratum of micaceous schists[1] occurs in wells about 4 miles to the south-east of Japog." (Inland Customs Report, 1870-71, p. 113).

Outcrops of these schists occur on the shores of the lake near Japog and several other places. They belong to the Arvali series of rocks, of which mention will presently be made.

Calcareous deposits of considerable thickness are of frequent occurrence round the shores of the lake. They are well developed near Sámbhar and Nanwa. These deposits are apparently formed by the infiltration of water into the blown sand forming the banks of the lake. Upwards of 20 feet of this concretionary limestone is exposed in a well sunk on the southern shore of the lake near Kotarsina.

The following statements relating to the specific gravity of the lake water is taken from Mr. Adams' report for 1870-71 (*l. c.* p. 115):—"The specific gravity of the lake water during the past rains never was less than that of sea water, the specific gravity of sea water being given as 1·03, while the lake water on 30th July gave 1·03. In August about 5 inches of rain fell, and as the evaporation, owing to the humid state of the atmosphere, was slight, the specific gravity was the same as that at the end of July. During September the specific gravity kept at 1·04; in October it increased from 1·05 to 1·07; in November it varied from 1·08 to 1·10; in December, owing to some slight showers of rain, it was reduced to 1·095; in January it increased from 1·11 to 1·14; in February it increased from 1·15 to 1·20, and at this specific gravity salt began to deposit. No difference of gravity was at any time observed in the brine taken from the surface and that taken from the deepest part of the lake.

[1] It is to be presumed that the 'sand' of the preceding sentence is decomposed schist.

"The specific gravity of a saturated solution of salt is 1·2046, but on the 9th March the specific gravity of the highly concentrated lake brine was 1·22, and on the 30th March 1·245. In this state the chemical solution is so dense that precipitation in the form of truncated pyramid-shaped crystals (the well-known form of the Sámbhar salt) is constantly occurring, until a layer of salt about 2 inches in thickness overlies the mud of the lake."

Dr. H. Warth gives the following analyses of the lake brine (*l. c.*, 1871-72, p. 155):—

"The samples examined were as follows:—

1. Lake brine—
   - A.—Common brine from the lake, 10th December, 100 yards from the shore near Japog.
   - B.—The same brine artificially saturated.
   - C.—Brine from Japog, 24th January.
2. Subterranean brine, or percolation brine, taken from diggings in the lake bed at places where the surface water had receded—
   - A.—Brine from reservoir in walled enclosure No. 2, 10th December.
   - B.—Brine from the same, on 13th January.
   - C.—Brine from a hole made on the shore near Japog, 10th December.
3. Mother-liquor—Residue brine from the manufacture of salt in *kyaris*—
   - A.—Mother-liquor from walled enclosure, No. 2, December 1869.
   - B.—Mother-liquor from the same, 17th January 1870.
   - C.—Mother-liquor from walled enclosure No. 1, 26th January 1870.

Analyses.

	Lake Brine.			Subterranean Brine.			Mother-Liquor.		
	A.	B.	C.	A.	B.	C.	A.	B.	C.
Dry residuum ...	21·9	27·1	27·8	22·7	20·8	20·1	30·6	30·4	30·4
Water	78·0	72·6	72·2	77·5	79·3	80·0	68·8	68·8	68·4
Chloride of sodium ..	19·9	24·6	24·8	19·7	17·5	17·3	19·1	20·5	19·4
Sulphate of soda ...	1·6	2·0	2·6	2·5	2·5	2·5	7·1	9·4	6·5
Carbonate of soda ...	0·4	0·5	0·4	0·5	0·8	0·3	4·4	0·5	4·5
TOTAL ...	99·9	99·7	100·0	100·2	100·1	100·1	99·4	99·2	98·8
Percentage of foreign salt in dry residuum ...	9·1	9·2	10·8	13·2	15·9	13·9	37·6	32·6	36·2
Average	9·7			14·3			35·5		

Analysis of clay from Lake-bed.—"The sample was taken from the Lake-bed, some feet under the surface, when the reservoir was being excavated, in walled enclosure No. 2, in December 1869.

Water	38·9
Silica	25·0
Oxide of alumina, iron, &c.	8·6
Carbonate of lime	8·1
" of magnesia	3·4
Chloride of sodium	18·1
Sulphate of soda	2·6
Carbonate of soda	0·3
TOTAL ...	100

"Proportion of foreign salts in the soluble substance, 18·1 per cent."

The Didwána salt lake—is situated about 20 miles to the west of the Arvali range and 35 miles from the Sámbhar lake in a north-westerly direction. It is about 4 miles long and 1½ miles broad. During the rains there is mostly a foot or so of water in the lake, but which soon dries up. When I was there in November it was quite dry, with the exception of a few patches of mud.

The origin of the lake is similar to that of the Sámbhar lake. It is situated under the lee of a short ridge, between 300 and 400 feet in height above the level of the plain, and so protected from the blown sand, which about here forms long ridges sometimes upwards of a 100 feet high, extending in an east-north-east direction. This is also the direction of the longer axis of the lake.

Two dams are built across the lake at about three-fourths of a mile from either end, to cut off the access of surface water.

The mode of procuring the salt differs from that at the Sámbhar lake. At Didwána wells of about 6 feet in diameter are sunk in the bottom of the lake to a depth of about 15 feet, the bottom of the well is then pierced to a further depth of 2 or 3 feet, by a heavy iron-shod pole, when the brine rises suddenly to within 4 feet of the mouth of the well, at which level it constantly stands during the hot weather and the rains. When the wells are first pierced large quantities of sulphuretted hydrogen gas are evolved, and even in the old wells the smell of the gas is very strong.

The sections exposed in the wells consist of alternations of sand and sandy calcareous tufa.

The brine from these wells has a specific gravity of about 1·2. It is lifted by the *chanat*, or lever bucket, into shallow pans of about 20 yards square and allowed to evaporate, when the salt is collected.

The manager of the works told me that the cost of manufacture was only Re. 1 for 200 maunds.

The Kachor-Rewassa lake—is situated in Shaikhawáti, about 30 miles north of the Sámbhar lake. It is very shallow, and when I was there, perfectly dry, and no manufacture of salt was being carried on.

Geological features.—The rocks forming the Arvali range belong to the gneissic or metamorphic series and the lower transition or sub-metamorphic series. The latter series consists of schists, slates, limestones, and quartzites, and has been called the Arvali series. All the sections across the range show that the rocks have been greatly disturbed, folded, and repeated several times. The dip is always high, seldom less than 70°, and often vertical. The most prominent features in the range are formed by the quartzites, the highest member of the Arvali series; thus, Táragarh hill near Ajmere, 2,855 feet above sea level, is formed of this quartzite, as well as the ridges immediately west of the Sámbhar lake, one of which rises to the height of 2,430 feet, and the ridges of quartzite, of the southern portion of the range, south of Todgarh, attain an elevation of upwards of 4,000 feet above the sea.

Complete sections of the Arvali series, from the gneiss to the top quartzites, are exposed both to the south, near Ajmere, and to the north of the Sámbhar lake in Shaikhawáti, but in the neighbourhood of the lake only a skeleton of the range is left, consisting almost entirely of vertical ridges of quartzite, the lower and softer slates, schists, &c., having for the most part been worn down below the level of the plain and covered by the alluvium and blown sand.

Several outcrops of the Arvali schists occur on the shores of the Sámbhar lake, particularly a few miles west of Sámbhar. The only other rocks exposed are portions of two broken, roughly parallel ridges of quartzite, one at the western end of the lake, and the other near the centre, a short distance east of Nanwa. The famous marble quarries of Makrána are situated on the western side of the range, about 10 miles due west of the lake.

No rocks are exposed in the bed of the Didwána lake, but a considerable thickness of slates occurs in the hills a short distance to the west; there are also some hills of quartzite at Kolia and Patan, a few miles distant from the lake.

Besides the metamorphic and sub-metamorphic rocks of which the central range is composed, another series of rocks, the Vindhyans, occur near it on the western side. The eastern boundary of these Vindhyans runs from Sojat to Khátu, at a distance of about 20 miles from the western edge of the range. West from this line they extend almost continuously to the west of Jodhpore. The Vindhyans of this area consist of sandstone, limestone, and conglomerate; they are but slightly disturbed, being mostly horizontal, and seldom dip at a higher angle than 5°. They rest quite unconformably upon the Arvali series. Good sections of this unconformity are exposed both at Sojat and Khátu, where the nearly horizontal sandstone of the Vindhyans rests upon the edges of the vertical Arvali slates.

As no fossils have as yet been found either in the Vindhyan or Arvali series, their age cannot be determined with any certainty. There is a great break between the Vindhyans and the Gondwánas, the next series in ascending order; and as the lowest group, the Talchirs, of the latter are probably permian, the Vindhyans are not likely to be younger than the carboniferous and possibly much older. The unconformity between the Vindhyans and the Arvalis is very great, it is almost necessary to suppose that the Arvali range was formed previous to

the deposition of the Vindhyans, in which case the Arvali series would be of very ancient date, probably cambrian.

The favourite theory to account for the origin of the salt in Rajputana is, that the rocks of the Arvalis belong to the "Permian system," which is confounded with the saliferous rocks of England; and that the salt of this region is derived from some of these beds as yet undiscovered, being dissolved by the rains and rivers and redeposited in the shallow lakes.

I have already shown that both the Vindhyans and Arvalis are older than the permian; but this would not dispose of the assumption that either one or both of these series might contain salt beds. As the lower beds of the Arvali series are covered by the alluvium and blown sand in the neighbourhood of the Sámbhar and Didwána lakes, it is impossible to say that salt beds do not exist in that position; but it is evident, from the wide distribution of the salt, that it could not be derived and distributed in the alluvium from one or two local sources, and therefore, if the origin of the salt be in the rock, its occurrence there must be frequent, and the probabilities of detecting it (or traces of it) *in situ* would be very great.

I have examined a very large area occupied by the Arvali series, from the extreme northern end of the Arvali range to within a short distance of Mt. Abu, without finding any trace of a salt deposit, notwithstanding the numerous complete sections of the series that are exposed, from the gneiss to the highest known beds.

There seems even less probability of salt escaping detection in the Vindhyans; for in the very large area covered by them in this region, both to the south-east and to the north-west of the Arvali range, the whole formation is exposed, from its very base, without any contortions to favour the concealment of peculiar beds, yet no trace of a salt deposit has been observed.

The artificial lakes, wells, and rivers afford stronger evidence that the salt is not derived from either the Arvalis or the Vindhyans. There are several large artificial lakes and tanks within the range at elevations greater than that of the plains. The principal of these are the Ana Ságar at Ajmere, situated in an eroded anticlinal fold of the Arvali strata in the centre of the range, Pohkar lake near the western side, and the Rae Samand at Kankroli on the eastern side of the range. The water supplying these as well as the numerous smaller tanks of the range flows over more or less complete sections of the Arvali rocks, and is in all of them sweet.

Of the numerous wells sunk in the Arvali rocks of the range, I do not remember that the water in any of them was brackish.

The Luni river, and its numerous tributaries draining the greater portion and a long length of the Arvali range, contain sweet water as far as the western edge of the range; but after flowing some distance over the plain to the west, the water becomes saline, and salt is deposited on the banks in the hot season, when the rivers cease to flow. At Pachbadra, 35 miles south-west of Jodhpore, large quantities of salt are manufactured in a valley near to, and probably an old bed of, the Luni. The Banas river and its tributaries flowing to the

east, drain a considerable portion of the range, and the waters remain sweet throughout.

The wells sunk in the Vindhyan rocks, on the western side of the range, contain, without exception, sweet water, while those sunk in the alluvium a short distance off contain brackish water.

As it seems improbable that the salt is derived from either the Arvali or the Vindhyan series, the only visible source remaining is the alluvium. It has been suggested that the alluvium is, in part at least, of marine origin, and that the salt lakes are parts of the old sea bottom in which the salt has accumulated. As no good sections of the alluvium west of the Arvali range are exposed, the beds of all rivers being shallow, seldom more than 20 feet below the level of the plain, and as large areas, more especially in the northern portion, are covered by blown sand, it is difficult to produce any direct evidence on this point.

Mr. Blanford found a mollusk (*Potamides layardi*), an inhabitant of salt lagoons on the coast, in one of the salt pools near Umerkot, from which he inferred that an arm of the sea extended as far as this in recent times. But Umerkot is more than 300 miles nearer the sea and several hundred feet lower than the level of the plain near the Sámbhar lake. In the portion of the alluvium that I have examined, extending south to 25° north latitude, I have not seen a marine shell; but in several places, in the old banks of the rivers, I have found fresh-water shells of existing species.

In my examination of the alluvium west of the Arvali range, I met with several ridges, many miles in length, of water-worn boulders, often as much as 1 foot in diameter. Nearly all of them were formed of the hard quartzite of the Arvali series, and must have undergone much rolling to reduce them to their present shape. A short distance west of Khátu, and about 35 miles west of the Arvali range, there are two parallel ridges formed of these boulders, about a mile apart at their nearest points and about 6 miles in length, running nearly north and south. How far north they may extend I am unable to say; but to the south they reach in a broken line to the Luni river, a distance of upwards of 70 miles. The boulders sometimes rest upon the Vindhyans, and are frequently isolated in the alluvium. The base of the ridges is never above the level of the plain. The boulders are clearly superficial to the Vindhyans and of comparatively recent origin; but whether they mark the course of a large river or of an ancient coast line, it would be rash at present to decide.

General conclusions.—If the question of origin from rocks underlying the alluvium could be decided from all that is visible of these rocks above the alluvium, and if the whole nature of these covering deposits could be told from what we can see of them in shallow sections at the surface, the answer in both cases would be in the negative, and the only source remaining for the salt would be its local production from natural causes still in operation. Theoretically the case is possible, as any modern schoolboy knows that lakes without an outflow, and to a great extent the ocean itself, become saline from the continual concentration by evaporation of what we call sweet water. In the present case, however, the process with known data seems inadequate to the result. For a long time the

production of salt from the Sámbhar lake has been on an extensive scale, and, as a source of salt, the lake dates from the mythical age. Myths are, no doubt, still a popular product of contemporary invention, and I cannot say whether historical documents throw any light upon the remote statistics of salt manufacture at Sámbhar. But the facts in hand are sufficient, without appealing to ancient history; and I have seen no mention of any symptoms of failing in the supply. To accomplish so much within any reasonable time, with a catchment basin of only 2,000 square miles, would seem an impossible feat, and we must not forget that the formation of the lake itself, as already described, is apparently due to conditions that are, at least geologically, modern; the reign of sand in Rajputana may almost certainly be assigned as a result of the reign of quasi-civilized man, the Rajput and his compeers; for it can scarcely be doubted that it was once in the possession of the forest primeval.

In this connection it has been considered whether we might not call in the aid of some of the great northern rivers. It is well known that the Satlej formerly flowed far to the east of its present course, and it is geologically possible, or even probable, that the Jumna once upon a time flowed through Rajputana, west of the Arvali range.[1] The waste waters of those rivers, distributed widely by overflow and percolation, before the channels became diverted into lower ground, must have supplied to the soil a very large amount of saline matter, and under suitable conditions of evaporation and percolation this might be retained in those upper deposits. At the present day all the rainfall on the tract between the Jumna and the Satlej, where is now the 'divide' between the basins of the Indus and the Ganges, including the water of some considerable streams from the Siwalik hills, is wholly dissipated or absorbed within that area, there being little or no escape by surface drainage. It seems, however, that this aid cannot be called in at Sámbhar, without almost inadmissible assumptions as to changes of level. There is certainly no room to suppose that the area under consideration has suffered from erosion; and at present the alluvial spill from the Himalaya on the north meets that of the Arvali from the south about Hissar, where we find the lowest ground in the cross-section of the Indo-Gangetic plains at their watershed. The elevation at Hissar is 700 feet, or nearly 500 feet lower than the Sámbhar lake, 160 miles to the south.

There is yet another fact to be considered in this discussion. Without exception, so far as known, sweet water is obtainable from the alluvial deposits at lower levels than the saline water. I cannot say that this has been tried at any actual focus of salt production, but it is a fact of universal experience and practice in the region under notice and throughout the plains of north-west India to sink deep wells for fresh water, where the upper water stratum, as very often happens, is too salty for use. It might seem at first sight that this fact would at once put out of court a question we have had to leave undecided—whether there may not be recent marine deposits below the surface alluvium, which latter is everywhere proved by its fossil contents to be of fresh water origin; but it is abundantly proved that strata which must have been originally impregnated with

[1] *See* section, 'The Plains,' in the Gazetteer of the Punjab.

salt water become purged by the forced circulation of fresh-water underground from artesian pressure, so our fact is of small account in the argument for or against marine strata in the alluvium. It is, however, of great weight in the argument for the local and actually operative production of these deposits of salt; for it is almost beyond question that, as a common phenomenon in Upper India, the saline condition of the upper water stratum is due to the present operation of assignable conditions upon the surface and subsoil waters, whether rain water or as derived by percolation or irrigation from rivers and canals.

With such good evidence of a *vera causa* of salt production actually in operation, it should certainly be an object of continued observation and study whether such extreme cases of local concentration may not be brought within its action. It may, nevertheless, be well to point out what alternatives remain for those extreme cases. We can, I think, confidently assert that the Arvali formation (or rock series) is not the repository of rock-salt. These strata occur in many outliers far into the alluvium on the prolongation of the range, and always in the same condition of extreme disturbance. There is a strong probability that what is seen of them in natural outcrops throughout the range may be taken as fully representative of the whole series. Of the Vindhyans it may be asserted with even greater certitude that, so far as seen, they do not and never did contain rock-salt. It has even been conjectured that this formation, so far as known, is of fresh-water or subaerial origin; but this very conjecture might encourage the supposition of contemporary salt deposition in contiguous areas; while the undisturbed condition of these rocks would be in favour of the total concealment of any such deposits at a lower level than the actual outcrops. The area of covered ground here is quite extensive enough to conceal any such deposits of Vindhyan or of any subsequent age; and thus there remains the possibility of such a source for the salt of Sámbhar and of other localities of apparently unlimited production.

RECORD OF GAS AND MUD ERUPTIONS ON THE ARAKAN COAST ON 12TH MARCH 1879 AND IN JUNE 1843.

The following reports by the local officers upon cases of eruptive action on the Arakan Coast are in continuation of those published in the Records for February 1879, Vol. XII, p. 70:—

From LIEUT.-COLONEL W. W. PEMBERTON, Deputy Commissioner, Kyouk-Phyoo, to the Commissioner of Arakan, Akyab,—No. 41-14, dated 23rd June 1879.

Referring to your endorsement No. 451-222, General, dated 7th May last, on the subject of a recent volcanic eruption, I have the honour to state as follows:—

The Extra Assistant Commissioner of Cheduba was asked for a report on the subject, and in his reply he states that the eruption did not occur on the island of Cheduba. Some fishermen, who were out at sea-fishing at the time of the occurrence, told him that they had

observed the phenomenon and thought it occurred on the island of Ma-Gyee, while persons residing on that island said they had seen the illumination seawards north of the island. The Extra Assistant Commissioner then states that afterwards he was informed by a Burmese medical practitioner who happened to be at Sandoway on the night of the occurrence, that the explosion took place on a small island situated south of the Tha-dai-chyoungwa creek, in the Sandoway district, which statement was corroborated by some fishermen who came from Kha-Mongdoon, in the Sandoway district, and who happened to be fishing at sea at the time the phenomenon occurred.

Previous to the receipt of your letter under reply, I had heard of the occurrence, and sent to the Extra Assistant Commissioner of Cheduba for a report on the subject, but the outbreak of cholera in the town prevented him from making the enquiry for some time.

From MAJOR M. C. POOLE, 'Deputy Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—No. 3-49, dated 29th April 1879.

In continuation with the subject of your letter No. 95, dated 4th instant, I have the honour to mention that when at Htsengoung on the 12th March, I saw the sky brilliantly illuminated by an eruption of the volcano at Cheduba. Some of the Burmans with me going on shore and looking across the sea in the direction of Cheduba distinctly saw the flames. You have doubtless received further details from the Deputy Commissioner, Kyouk-Phyoo.

FROM MAJOR M. C. POOLE, Officiating Deputy Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—No. 3-90, dated Sandoway, 31st July 1879.

In continuation of the subject contained in my letter No. 3-49, dated 29th April 1879, I have the honour to furnish all the additional information I have been enabled to collect regarding the volcanic phenomenon observed on the 12th March last. To my observation it appeared to emanate from some island lying north-west of Htsengoung; but not taking the bearings of the distant flames, I am unable to accurately define their position and joined in the hasty but not unnatural conclusion of the other spectators, that it was in the direction of the island, of Cheduba. I visited the village of Ka moun-doon on the 22nd instant, and there held conversation with some who had seen it; the day was beautifully clear, and from the slightly elevated shore, the southern extremity of the island of Ramree, the islands of Zagoo, Magree Kyoon, and Yey Kyoon, all stood out clear and distinct like a chart; in the distance could be distinguished the sharp serrated outline of hills in the island of Cheduba. The head-man of the village pointed out to me two sharp pinnacle-shaped rocks far out on the horizon, and known by the name of Kyouktabon which he said he was certain was the exact spot where the flames came from. These rocks lie south of Cheduba, and when viewed from Htsengoung, in a line with the north of that island and Yey Kyoon. This latter island was the scene of a similar occurrence in 1843, Captain Hopkinson's account of which I send a copy of. I am inclined to believe that most of these rocks and islands contain cavernous hollows in which petroleum or other gases are generated, and that they occasionally ignite and burst out. Several men who were at sea that night gave me different versions of what the aspect of the phenomenon was to them, varied of course by the different positions from which they saw it; I am of opinion, however, that the testimony of the headman at Ka-moun-doon is the most trustworthy, and my own opinion inclines to an endorsement of his view.

FROM CAPTAIN H. HOPKINSON, Officiating Senior Assistant Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—dated 25th November 1843.

Having, in compliance with the instructions contained in your letter to my address No. 838 of the 21st ultimo, proceeded to Rekeong or Flat Island for the purpose of making enquiries into the volcanic eruption which has recently been observed at the southern extremity of that island, I now beg to submit to you the result of my enquiries with all the information I have been able to collect in the matter.

2. Before I give the substance of the Thoogyee's deposition, I will endeavour to state what I saw myself, premising shortly that whatever island may have been formed by the sub-marine volcano has either sunk or perhaps, being merely composed of mud and loose volcanic fragments, has been washed away during the south-west monsoon, leaving no trace of its existence, and not even having disturbed the reef of rocks among which it is said to have arisen. I lament exceedingly my total ignorance of geological science which would most probably have led me to pass over much which was really valuable whilst I noted down objects of trivial importance, and which also prevents me from communicating any useful observation I might have made in such language as would be understood by a scientific person.

3. I arrived at Rugyoung on the third day after my departure from Sandoway, and immediately put myself in communication with the Thoogyee of the place, whose attendance to depose what he knew about the volcanic eruption and also to act as my guide to the site of their occurrence I procured for the following day. We started early in the morning and arrived near the small island in the vicinity of which the eruptions were remarked at 8 P.M. I was obliged to proceed for upwards of a mile from the island itself in the jolly-boat; reefs of sunken rocks running out in every direction preventing a nearer approach for the schooner, though otherwise the water was of a considerable depth, being from two to three fathoms within a boat's length of the little island itself. My office has not been furnished with a general chart of the province, and I do not know whether the island has been noted or not, but it may be easily identified, as I was careful to take its exact bearings to known points on the coast. I also made a rough survey of it by cir-cumferenter and enclose a sketch thereof, showing the bearings, site of volcanic eruption, &c.,&c. The rocks which formed the basis of the island were chiefly the common sandstone of Arakan, interspersed with large masses of rock, of which No. 1 of the specimens I had the honour to forward in the *Swallow* is a fragment. I could obtain no distinct traces of strati-fication on any part of the island, the action of the sea having broken up its surface into a confused mass of rocks. I have marked on the map the site of the volcanic eruption as given by the Soogree, but further than the mere direction goes, I do not think much dependence can be placed on its accuracy. The Soogree never visited the volcanic island; the eruption occurred during the height of the rains, when it is seldom clear for even a few hours, and the Soogree's nearest point of observation was, I should say, at least 4 miles distant. I should infer that the eruption must have been on a small scale, since from the testimony of the natives it appears that none of the numerous rocks near which they were observed have been altered in position, neither cast down nor upraised. I have marked on the sketch the situations from whence I took the different specimens before alluded to; the trap rock which I labelled hornblende was broken off a large rock about 12 feet square at top. The piece I have called felspar was from an adjacent rock, but smaller. I could only find the iron pyrites on the side nearest the volcano; there it was most plentiful, and I might have collected it by the maund; one specimen which I have called quartz is, I believe, limestone; its appearance at first misled me. On the sand mound I found large quantities of sponge of different kinds. I saw no coral on the island, nor any formation of it among the rocks, an unusual circumstance in Arakan. I looked for pumice, but did not find any.

4. The above is all that occurs to me to remark upon, and I shall now proceed to give the substance of the information gained from the Soogree: he states that in the month of Wageo or June, at about 8 o'clock in the morning, he observed the eruption for the first time, issuing apparently from between three rocks to the eastward of his village and about one hour's sail distance from it, to the south of Thee-byoo-gyoung-let, White Sand Island, the one in the sketch. The eruption was like fire of a bright red colour, and continued without intermission for three days, when it ceased, and deponent then observed that a small island has arisen from the sea; this island lasted for about a month, but he cannot say when it actually disappeared, for the weather was very boisterous during the whole time, and it was only by a calm supervening and the waves subsiding that he found the island had ceased to exist. The surface of the sea was as before, and not a rock was displaced; deponent did not visit the volcanic island, nor did any one in his circle, the fury of the waves prevented all approach to it. When he first visited the island nearest the site of the eruption, the only change he noticed was that some cocoanut trees had disappeared—probably been washed away—which were planted there about two years ago. During the time the eruption continued there was an unaccountable increase of water in the wells and tanks of his village; he also felt several slight shocks as of an earthquake during the time. The above, meagre as it is, is all the information I could obtain from the Soogree, but it was fully confirmed by the different inhabitants of Rekeoung whom I questioned on the subject.

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July 12th, 1880.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1880. [November.

On some Pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period, *by* W. Theobald, *Geological Survey of India.*

The deposits to which I propose to direct attention in the following notes are those commonly called 'recent deposits,' and as such commonly neglected, though, if patiently interrogated, they are capable of affording a key to the solution of some interesting questions bearing on mundane physics of no very remote age. I allude, of course, to the much-vexed question of the extension, universal or otherwise, of glacial phenomena during a 'great ice age,' and particularly of the proofs, *pro* or *con*, for the existence of any such glacial phenomena in or near the plains of India, or at so low a level in the Northern Punjab as 2,000 or thereabouts. So long ago as 1867, Dr. Verchere recorded the presence of 'erratic' blocks in the Potwar at less than 2,000 feet altitude (Jour., As. Soc., Bengal, Vol. XXXVI, Part II, p. 113); but from the known liability of the Indus valley to cataclysmal inundations, consequent on the bursting of dams in its upper portion, the true bearings of these masses have never been properly appreciated, nor has any attempt been made to study the facts in detail or interpret the relation they bear to the general geological history of the district, and to postulate the conclusions we may legitimately deduce therefrom. The following papers may be beneficially consulted as bearing on the matters in question, and I cannot better preface my present remarks than by briefly reviewing what has been already written on the subject, and pointing out which statements require modifying, and wherein I differ from, or coincide with, the opinions of the writers I quote below—

Wynne, Records, Vol. X, pp. 107, 112, 122.
Theobald " " X, p. 140.
" " " X, p. 223.
Wynne, Memoirs, " XIV, p. 116.
Lydekker, Records, Vol. XII, p. 29.
Wynne, " " XII, p. 114.
Blanford, Manual, pp. lxx, 372, 516, 586.
Medlicott, " p. 668.

In the first paper Mr. Wynne describes the relations and characters of the post-tertiary and superficial deposits of the North-Western Punjab. These deposits he divides into an upper alluvium (elsewhere termed loëss), largely imbued in places with soda salts, and much cut up by ravines; and a lower division formed of "coarse pebble beds and sand or clay." These beds are described as not only filling the valleys, but covering large tracts of country, as, for example, in the neighbourhood of Ráwalpindi and elsewhere. They are described as rising to 3,000 feet above the sea; but this estimate may be indefinitely extended, if we take into consideration the homologous deposits which were being cotemporaneously formed within the hills, and the high level gravels of the larger river valleys. Mr. Wynne's estimate, however, probably is meant only to include the deposits in the immediate vicinity of the outer hills of the Hazára district. The tertiary period may, in fact, be described as closing in a great subsiding movement of the Himalayan region, whereby the river valleys became filled up to the height of several hundred feet by coarse river deposits, and the whole country overspread by the gravels and the high-level alluvium which rests on them.

One remark of Mr. Wynne I believe to be erroneous. At page 124 we read, "With regard to the existence of a glacial period affecting the upper Punjab in very recent geological times, the only evidence the country seems to offer is in the occurrence of the formerly Indus-borne crystalline fragments at heights of some 2,000 feet above the present bed of the river. These would indicate either a very late elevation of the region traversed by the Indus, or, that when it ran in a channel so much higher, the hilly country to the northward may have been as much more lofty (or even higher still), and regions of perennial snow much nearer than they are at present." The above passage is couched in general terms, but I have reason for knowing that it particularly refers to the Chitapahár range south of Attock, and the word 'fragments,' which might be supposed to refer to 'erratics' really means only the rolled boulders of the Indus gravel. As, however, I felt very sceptical that the Indus, abandoning its deep and rocky gorge to the west of the Chitapahár hills, had ever really flowed here and there over the crest of that range, I addressed enquiries on this point to my colleague, and his reply, though intended, I think, to some extent as confirmatory of such an idea, really supports my own opinion on the subject to the contrary. In his reply, Mr. Wynne says:—"One swallow don't make a summer, one pebble would not make a gravel; *so I can't declare there is any big deposit of Indus gravel on the Chita range*, but all the same there are good large lumps of the Indus boulder deposits scattered about on the ranges of Bágh and Choi, at heights of 2,500 to 3,000 feet, too numerous to have been carried up by humans, *who would not load themselves with two or three seers or more of such stones (gneiss, &c.) and carry them up some thousands of feet for the fun of the thing, or as prisoners do shot drill.*" Now I think these words of my colleague establish the fact that there is no *deposit* of gravel on the Chitapahár range, and that the inference of the former course of the Indus over its height rests on the occurrence of scattered boulders of Indus gravel, and in ignorance of any reason for supposing them to have been transported to the spot in question by human agency.

But a good and sufficient reason does exist for this latter explanation. It is

the habit in all this part of the Indus valley to collect boulders from the vicinity of the river and convey them away on carts or camels for the purpose of strengthening the mud-walls of the houses. Near the river the walls of many houses are mainly built of the larger boulders, whilst at a greater distance, the builders use these stones more sparingly, building them into the corners of the house only, where they protect the mud-walls from injury from passing cattle, &c. In many villages, too, a very old trait of patriarchal times may still be seen. Any very large smooth boulders or stones from Buddhist or other ruins, are brought up into the village, and either ranged under a tree or placed in some convenient spot for the use and delectation of the village headman, and 'grey beards,' precisely as we read in Homer, was the case in Pyle in the days of Neleus, three generations of articulate-speaking men before the fall of Troy. (Hom. Od., Book III, l. 404.)

> Ἦμος δ' ἠριγένεια φάνη ῥοδοδάκτυλος ἠώς
> Ὤρνυτ' ἄρ' ἐξ εὐνῆφι Γερήνιος ἱππότα Νέστωρ
> Ἐκ δ' ἐλθὼν κατ' ἄρ' ἕζετ' ἐπὶ ξεστοῖσι λίθοισιν
> Οἵ οἱ ἔσαν προπάροιθε θυράων ὑψηλάων
> Λευκοὶ, ἀποστίλβοντες ἀλείφατος οἷς ἔπι μὲν πρίν
> Νηλεὺς ἵζεσκεν θεόφιν μήστωρ ἀτάλαντος·
> Ἀλλ' ὁ μὲν ἤδη κηρὶ δαμεὶς Ἀιδόσδε βεβήκει,
> Νέστωρ αὖ τότ' ἔφιζε Γερήνιος οὖρος Ἀχαιῶν,
> Σκῆπτρον ἔχων περὶ δ' υἷες ἀολλέες ἠγερέθοντο·*

An even more probable explanation for the occurrence of Indus gravel at different spots on the Chitapahár range is the popular fashion of ornamenting graves in this part of the Punjab with smooth round stones, those of white quartz and variegated gneiss or schistose rock, being selected more commonly for this purpose. This practice may be noticed many miles from the river Indus, and proves that natural piety is as effective a stimulus for an unproductive expenditure of labour, as the harsh necessity of "shot drill;" and to this latter cause I attribute the presence of the Indus pebbles occasionally met with at considerable height on the Chitapahár hill. In many spots villages formerly existed, which are now abandoned in favour of the plains, owing to the security for life and property which the people now enjoy.

* 'Soon as Aurora, daughter of the Dawn,
With rosy fingers, had unveiled the morn;
From off his couch, Gerenian Nestor rose,
And issuing forth, refreshed by night's repose,
On polished stones, before his palace gate
As Neleus used of yore, the monarch sate.
White, smooth, and glittering in the sun they shone
Unhewn, each block displayed a rustic throne;
But Neleus passing to th' Elysian shade
Wise Nestor reigned and Pyle's sceptre swayed,
Whilst numerous sons around, obeisance made.'

I have myself crossed the Chitapahár range twice, and have both times carefully sought for evidence of the Indus having formerly flowed over it, but without success, and I believe that river has never deviated from the deep gorge whereby it now crosses this barrier. The highest alluvial deposit which can be referred to the river Indus in this quarter, is a homogeneous clay, which is seen in places on the flanks of the range south of Choi,[1] rising to a height (roughly guessed) of between 300 to 400 feet above the present bed of the river.

This clay may possibly be of lacustrine origin if the Chuch Hazára plain and neighbourhood were ever occupied by a lake prior to the lowering of the Indus bed to its present depth. Anyhow I should say 400 feet was the highest level on the Chitapahár range above the present Indus bed, at which any distinct Indus alluvium can be made out. So much for positive indications.

But there is one very powerful negative argument against the idea of the Indus ever having hereabouts flowed at the height indicated by Mr. Wynne.

Above the limits at which the clay in question occurs, the hills are formed of vertical beds of limestone, cut up or furrowed by deep, almost cavernous, fissures, forming a deeply *serrated* surface, which would have acted as the most efficient pebble trap that could be imagined, and into which any pebbles must have been washed, without the possibility of their being subsequently cleared out again. Yet not a single pebble or boulder of any sort can be seen in any of these rifts, the conclusion being therefore irresistible that no wash of gravel has ever taken place over them.

The next papers to notice are two by myself in Records, Vol. X, pages 140 and 223. In the former I describe an alluvial deposit in the Potwar with numerous species of living shells, and a peculiar silt near Jand, possibly indicative of glacial conditions at the time it was being deposited. Perhaps the most important fact, however, was the occurrence of a large 'erratic' "over 20 feet in girth, *resting on alluvium at a high level*, eight and a half miles from Pindigheb and eleven miles from Taman" (l. c., p. 142). This is a valuable indication of the relative age of the glacial conditions presumed to have obtained in the district, and the older alluvium; the instance here quoted not admitting of any doubt as to the fact of the 'erratic' reposing on a thick bed of alluvium. My other paper refers to certain distinctions that should be drawn between 'erratics' of the pleistocene period and the 'erratics,' which in the Salt-range are embedded in strata of mesozoic and palæozoic age, and which are as distinct in their lithological aspect, as they are from the Indus erratics by their geological age. In his Memoir on the Salt-range (Vol. XIV) in a note to page 117, Mr. Wynne thus correctly, as I believe, alludes to the 'erratics' of the Indus valley:—"In other parts of the country, too, along the left bank of the Indus south of Attock, the foreign erratic blocks are too numerous and too large to be accounted for satisfactorily in any other way that I know of." That is, than by ice agency. Two of these are described in Records X, p. 124, as having a girth

[1] Choi is not on the Atlas map. It is, however, a little under 3 miles from the mouth of the Haro on the south bank of that river, and is a halting stage (with a 'sarai') on the road from Attock to Khushálgarh.

of 50 feet by 6 to 8 feet high, and 48 feet 6 inches by 12 feet 6 inches high; the former a granitoid rock, the last of basalt.

I now pass to the consideration of a clearly-written and valuable paper by Mr. Lydekker in Records XII, p. 15, in which the glacial question is treated at some length. Among general conclusions my colleague affirms that in Kashmir 6,500 feet is about the lowest level at which "undoubted evidence of former glacier action" exists. This, I think, may be true, as I have myself been struck with the remarkable absence of such evidence in the valley, though I never questioned the existence of such evidence at much lower levels in the outer hills. The cause of this, should the statement not require modification, is I regard an interesting object for future investigation. Mr. Lydekker differs also from Prof. Leith Adams in his failing to recognise any proofs of a glacial origin for the Báramula gravels, and in this I agree with my colleague. At page 30 (*l. c.*) Mr. Lydekker records his dissent from Colonel Godwin-Austen's opinion that certain granitoid blocks in the Jhelum valley below Báramula have been brought to their present position by ice action. Here I dissent from my colleague, and consider that Colonel Godwin-Austen has rightly estimated the mode of transport of these blocks in question. In support of his view my colleague goes at some length into a description of the Jhelum valley, which, being clear in language, and conveying completely my own views, I shall here quote *in extenso.* That my colleague has arrived at a different conclusion to myself, I attribute solely to the accident that he has not seen such a 'key section,' as I may term it, as I was fortunate enough to discover during last season's work in the valley of the Nainsukh, above Gurhi Habibula :—

"At Rámpur the alluvial formation contains gneissic blocks, some of which are as much as 15 feet in diameter; the whole formation is at least one hundred feet in thickness on the left bank of the river. The included blocks are all more or less rounded and water-worn, while the matrix in which they are embedded is here but little stratified. As we descend the river, the blocks of gneiss continue to decrease in size till we come upon the sharp bend in the river below Rampur; here a fresh stream of gneiss blocks has come down a tributary stream from the second gneiss mass in the Káj-Nág range: some of these blocks have a long diameter of 20 feet.

"Still continuing our survey down the river, we find the gneiss blocks again becoming smaller and smaller, and half way to Uri the alluvial deposit is seen to be most distinctly stratified. All the gneiss boulders have their long axes inclined up the stream and towards the river bed at an angle of about 30°; so that one of the flat sides is opposed to the flow of the stream, as we find to be the case in any deposit of modern river pebbles. The summit of the alluvial formation is level, forming high-level plateaux on either side of the river. At Uri we find a similar plateau, some 200 feet in thickness, formed of the red Sirmur rocks of the neighbouring hills. The pebbles in this deposit are rounded and have the same relative position in regard to the stream as the gneiss blocks higher up. A few small gneiss blocks are found in the Uri deposit."

Now all this I fully accept as a correct description of the Jhelum terrace gravels and boulder deposits, for I regard it would be as one-sided in me to

either fail or refuse to recognise the agency of water in their arrangement as I hold it to be in any opponents who fail to recognise the proofs of glacial agency concurrently present in the same area.

I do not point to well-rounded boulders embedded in a stratified deposit, with their long axes arranged with reference to the direction of the river, as proof of glacial agency; but I do point to streams of blocks not so rounded, but sub-angular and piled on one another, with little or no intervening matter, in a fashion suggestive of moraine rather than river transport. It is true the rock of which the largest blocks consist rounds off by surface exfoliation under atmospheric action; but the streams of sub-angular blocks, to which I allude, have no nearer resemblance to the water-worn boulders described by my colleague than accrues from their consisting of the same identical rock. As an instance in point I may mention, on the right bank of the Jhelum the stream of blocks which is seen to descend the Kathai stream just below the Fort of Kathai, and is buried in the surface of the high level plateau before reaching the Jhelum. These blocks are scattered about, *sometimes isolated on the surface of the alluvial plateau whereon they rest, in other places ranged in clusters or piled against each other with little or no intervening matter; and they are all more or less sub-angular, and have none of the appearance of having been washed down the valley or by the stream.* Granting, for argument's sake, that a great debacle might have washed them down, it would not have arranged them in a long thin line, heading up the valley; in a word, their arrangement is decidedly suggestive of moraine action as distinguished from fluviatile.

Mr. Lydekker adds (*l.c.*, p. 31):—"It will be gathered from the above observations, that the whole of the gneiss blocks in the Jhelum valley have followed the course of tributary mountain streams, have not been carried across intervening ridges, and are embedded *in* an aqueous formation." To this passage I can give my cordial assent, if I may interpolate after the word 'in', the words 'and on,' which in my opinion furnish the clue to the discrepancy of opinion between my colleague and myself. The rounded blocks to which my colleague points as conclusive of fluviatile agency may be, and no doubt are, embedded *in* river deposits; the sub-angular ones on which I no less confidently rely as proving moraine agency are, I believe, always found resting, not *in*, but *on*, the above river deposits.

There is one paragraph with which I cannot agree:—"It will be gathered from the above observations that the Jhelum is now a denuding, and not a depositing, river, as it was when these alluvial formations were laid down; from which we may probably infer that great changes of level have taken place since the period of these deposits, *which may have afforded greater facilities at certain times for the movements of the blocks*." This is far from clear. The 'change in level,' which converted the Jhelum from an excavating stream employed in deepening its bed into a depositing one, which it must have been when it refilled its valley with alluvial deposits 200 or 300 feet thick, was one of subsidence, whereby the *gradient* of the Jhelum valley, both the main channel and all its tributaries, was lowered,—the proximate cause, of course, of the deposition of the above beds: *cæteris paribus*, therefore, this change could neither

physically nor climatally have afforded greater facilities for the transport of large blocks than previously existed; rather the contrary.

In his "further notes, &c." (Record XII., p. 114), Mr. Wynne divides the pleistocene deposits of the Northern Punjab into an upper, middle, and lower sub-division, characterizing them respectively as "Northern detrital drift," "Alluvium and river drift," "Post tertiary valley or lake deposits."

It may be questioned how far the middle and lower of these sub-divisions are separable or dissimilar; but the great merit of this division is that it distinctly recognises the relative position of the 'glacial deposits' and the older alluvium, and shows how nearly on the verge of discovering the true significance of this fact Mr. Wynne was.

Mr. Wynne is, however, careful to let it be known that he disclaims glacial agency in the distribution of his 'Northern detrital drift', not only by introducing the somewhat superfluous adjective 'detrital', but by the definition he gives at page 132 (*l. c.*) :—"*Northern drift.* I use this term instead of the more simple one "erratic drift," which would appear to convey to some Indian geologists a closer connexion with glacial geology than is necessary to the purpose." This disclaimer suffices to show how nearly Mr. Wynne missed recognising the essential merit of his own classification. Especially when read in connexion with what follows:—"By Northern drift, then, is here meant that influx of travelled masses which has followed the course of the Indus from the north and been distributed over large spaces of the Ráwalpindi plateau, to a distance (I am informed by Mr. Theobald) of 25 miles from the river. These blocks are easily recognisable, all along the upper Indus as far as I went, to be the same as those further down its course. *They often rest on the terraces, and some of them are of very large size.*" Mark how very nearly discovering the truth Mr. Wynne must here have been (how he 'burned,' as children say at 'blind man's buff'), could he only have recognised the significance of their not occurring *in* the terraced gravels though scattered about *on* them! Considering, too, that Mr. Wynne gives the girth of one of these blocks near Torbela as 109 feet, his disclaimer of glacial agency on its transport seems to me to savour of caution overmuch! It would, indeed, seem to be an afterthought, as in his Geology of the Salt Range, at page 117, Mr. Wynne thus expresses himself of these very blocks :—"In other parts of the country, too, along the left bank of the Indus south of Attock, the foreign erratic blocks are too numerous and too large to be accounted for satisfactorily in any other way that I know of"—that is, than by ice; and it is, I think, to be regretted that Mr. Wynne should have been led to abandon this sound view, and substitute for it the disclaimer of glacial agency in his later paper, quoted above.

At the end of the paper in the Records (XII, p. 132), Mr. Wynne notices a detached mass of limestone 127 paces in girth, which may possibly be an 'erratic' slipped down from Sirban mountain, aided possibly by ice before the intervening ravine was cut, or, as I would suggest, when it might have been sheeted over by ice; and Mr. Wynne records the discovery by myself of glacial striæ on a block of quartzite below Torbela. I mention this to express my belief that the striæ in question are not glacial, as I once supposed they might be; but

what could have produced straight, but not parallel, scratches on a hard corneous quartzite, I cannot say. They may be glacial, but their varying direction makes this very doubtful.

To revert now to my own observations during the past season. I may commence by saying that a re-examination of the ground near Jand failed to verify the occurrence of 'erratic' blocks in the peculiar silt of that neighbourhood. The occurrence of 'erratic' blocks in this silt rests on two presumed instances recorded in my paper (Records X, p. 142) of such blocks being seen reposing *in situ* and partly embedded in the silt; but from the conditions of the case, such an observation requires corroboration, and hitherto my search for a section displaying such blocks embedded in the silt has not been rewarded with success; and the glacial character of the deposit may therefore be still considered as unsettled. That this silt is a lacustrine deposit, is, I think, more than probable, and that it is really the homologue of the coarse alluvial accumulations near Ráwalpindi, when the lower part of the Sohán valley and the adjoining region along the Indus, with the Chuch Hazára plain, constituted a lake through which the Indus flowed, and which owed its origin in part perhaps to that subsidence of the whole area to which the thick alluvial deposits in the Indus valley and its tributaries bear testimony. If my suggestion is correct, that this silt is the exact homologue of the clays and gravels to the east and north, it at once explains why no erratics are found embedded in it, though more or less widely dispersed over the area covered by it, since I shall presently show that the glacial conditions whereby the erratics in question became distributed, *supervened* on (that is, after) the deposition of the gravels in question. At page 516 of the Manual, Mr. Blanford suggests the idea of lacustrine conditions as contributing to the dispersal of these blocks, with the alternative suggestion of a "*variation in the course of the Indus, and to the reversed flow of its tributaries in great floods.*" I shall endeavour to show that each of these suggestions has its share in producing the phenomena under review. The lineal arrangement of these 'erratics' in the Potwár,—one line following the general direction of the Sohán valley, whilst a parallel train of erratics passed near Jand (Rec. X., page 142), could only have originated in two ways,—either through 'moraines' descending to the Indus trough, or through floating masses of ice sweeping up the tributary valleys during a reversed flow of the streams produced by floods. And the result would not be interfered with, supposing the area adjoining the river to have been temporarily covered by a lake, as the reversed flow of the streams falling into the lake, during the rise in its waters resulting from Indus floods, would suffice to establish a direct current, mainly coinciding with the old river channels, through the body of still water of the lake at large and constituting *water lanes*, along which the erratic blocks and floating ice could be carried, and to which the linear arrangement of the blocks now seen would be due. If, however, there was no lake, the 'reversed' flow of flood would produce this lineal arrangement of erratics, as a matter of course; but the presence of a lake would, I think, no less permit of a similar distribution of the blocks, and would fully account for their presence in the situations they are found to occupy, that is, on the top of the alluvium, as near Pindigheb, for example, and Taman.

Leaving the vicinity of Jand, which may be regarded as somewhere near the centre of the supposed lake, and proceeding north, we find an instructive section of these valley deposits near Pari, on the Nára river (3 miles east-south-east from Shádipur, on the right bank of the Indus) and about 15 miles from Jand. Approaching the Indus from the south-east, along the road leading to Pari and Shádipur, we see in front of us a long stretch of rising ground, more or less parallel with the river and decreasing in height away from the banks. The edge of this line of rising ground is very rugged and broken up by denudation, and the Nára river below Pari gives a clear section of the beds, showing that the rising ground in question is simply a belt of coarse beds, whose maximum thickness is attained in the immediate vicinity of the river, and which thins out away from its channel, owing to the coarser material being at once deposited, whilst the finer sediment only is conveyed to more distant parts of the valley. The bed of the Indus is here cut deeply in Siwalik sandstones, dipping mostly at high angles. On the edge of these beds rests a thick alluvial deposit, divisible into a lower or conglomeratic portion, and an upper division of clays in which the conglomeratic element is wholly subordinate—the united thickness of both divisions along the river not falling short of 80 or 100 feet, though how much has been removed by surface denudation, it is impossible to say. The lower conglomerate is very coarse and heterogeneously composed, the largest boulders in it being of nummulitic limestone, commonly 3 or 4 feet in girth; and often sub-angular, the ingredients being evidently derived from the Chitapahár range only a few miles distant to the north. This deposit is clearly a coarse river gravel, but although very large blocks occur in it, I did not notice decisive proofs of glacial conditions—that is, any monster blocks of the Hazára gneiss actually in it. In the valley of the Nára river, however, one mile east of Shádipur, I noticed two huge 'erratics' not far apart, one of Hazara gneiss 50 feet in girth, and one of nummulitic limestone 60 feet in girth; but although these might have been derived (from the position they were in) from the coarse bottom bed above described, they might equally have been let down into the stream bed from a higher position by mere denudation, and this view is supported by other considerations I shall soon adduce. All about Pari, too, large craggy masses of limestone are scattered, which may be doubtfully referred either to this coarse bed or to ice flotation at a later period; and their distance from the river, and their being out of the direct line of its floods properly so viewed, render the latter supposition, I think, the preferable one. Above this coarse bottom bed occurs a group of clays of equal thickness, or greater perhaps, away from the immediate vicinity of the river. This clay in places contains a little kankar, and forms the general surface of the country hereabouts; and on its surface genuine erratics are here and there seen of the Hazára gneiss, which, as I believe, can have been only so brought by ice flotation; and if we regard the basal conglomerates as local deposits, resulting from the proximity of the Indus gorge (below Níláb Gásh) and the Chitapahár range, the homology between the Jand silt and the ordinary valley alluvium is clearly seen, both resting on the denuded sandstones, wherein the river has now deeply sunk, and both supporting genuine 'erratic' blocks of a later period.

Leaving now the Potwár, and crossing the Chitapahár range, we descend into the valley of the Hurroh (which joins the Indus at the rectangular bend that river makes to the west), at Nílat, where the old royal road from Peshâwar to Hindustan used to cross, and both the Haripur and Chuch plains offer some points of great interest in connection with their recent deposits and the physical changes of surface they reveal.

The Haripur plain is bounded on all sides except to the south-west by hills, and is composed of a deep alluvial deposit, the older rocks not usually appearing, away from the hills which bound the valley. South of the old cantonments of Haripur, the whole of the drainage of the valley is conveyed into the Hurroh river; whilst that to the north finds its way into the Dorh, which, after being joined by the Siran, flows into the Indus above Torbela, past the northern extremity of Gandgarh mountain, which is interposed between that river and the Haripur plain. No erratics occur in any part of the Haripur plain, and the valley of the Hurroh is wholly free from them till within a mile or less of the spot where the Peshâwar trunk road crosses the stream. Down to this point the valley may be said to be sheltered by the mass of Gandgarh; but directly the lower ridges south of Gandgarh are passed (going west), 'erratics' of Hazára gneiss, or the Indus 'erratics,' as they may be called, appear in some force, and from the spot where the road crosses continue *down the valley of Hurroh as far as its junction with the Indus at Barotha.* These 'erratics,' as I have stated, have not descended the Hurroh valley, but have cut abruptly into it from the Indus, below the sheltering barrier of Gandgarh, or, in other words, the former course of the Indus coincided with the present course of the Hurroh, west and south of that mountain. This will be rendered clear by a glance at the accompanying sketch map, whereon is marked the course of these Indus 'erratics' and their distribution in this neighbourhood; and it will be at once apparent that at no remote period the Kabul river joined the Indus—not, as now, at Attock, but close to Barotha, some 9 miles to the south. The whole of the country between the trunk road on the north and the Hurroh on the south, consists of rolling 'downs' of river alluvium, mostly sandy, with here and there a sprinkling of Indus gravel and boulders, and scattered 'erratics'—these last being specially numerous along the course of the Hurroh, as the annexed map will show.[1] Many of these erratics are of large size, 50 feet in girth or more, though of course the majority are smaller. They consist of Hazára gneiss or of limestone, which last rock has not travelled so far as the other. The sketches here given (see Plate) of one near Dakner and of another near Jand, by Mr. Wynne, will give a good idea of the general appearance of these blocks—those of limestone or of any crystalline schist being, from the nature of the rock, usually more jagged and angular than those of gneiss, which is so wont to 'flake off' at the surface.

No one, I think, who considers that the above 'erratics' (granite) have travelled from the most distant parts of Hazára, and are now seen reposing on a sandy plain, will entertain serious doubts as to their truly 'erratic' character, or that they have been conveyed by ice flotation to the positions they now occupy.

[1] See also Wynne's map, Records X, Part 3.

Erratic of Gneiss near Dakner 4. Miles S. S. E. of Attock.

J. Schaumburg, Lith.

Erratic of Gneiss below Jand and Khushalgarh.

Mr. Wynne also writes as follows (Records X, p. 124):—"*On one of the river terraces* of the Indus gorge, between Pari and Báhtar, I measured an 'erratic' mass of unfossiliferous limestone 9 feet high and 74 feet in girth, which may have belonged to any of the neighbouring limestones, from the lower nummulitic downwards, and seems to be as truly an erratic block as any of the others." No doubt this block had not travelled far, but it is interesting to find such a mass *on* an old river terrace, when the full significance is realised of such blocks occurring on the old gravels, but not in them, as would seem to have been always assumed as being the case, as a matter of course, by the opponents of glacial theories.

No less interesting, as proving the altered surface conditions now prevailing, are the indications afforded by the lower part of the Dohr valley, where it is joined by the Siran. Leaving Haripur by the Torbela road, which descends sensibly, and continues nearly parallel to the course of the Dohr, we come in sight, at about 4 miles, of what seems a low ridge stretching right across the valley and connecting the hills across the Dohr with the Gandgarh range of hills. A little to the left of this seeming ridge, and perched on the foot of the Gandgarh hills, is the village of Dari; and away to the right is Barukot. Approaching nearer, we find that the seeming ridge is breached right in front of us by the Dorh, after being joined by a small stream from the south, when it flows on and joins the Siran close to the village of Tapli. The road along the bank of the Dohr here affords an excellent section of the coarse boulder deposits which seem to constitute the ridge in question. On the Gandgarh flanks, round which the road winds, the deposit consists of coarse gravel and boulder conglomerates, with a good many Indus erratics strewed about the hill side and lying in the bed of the stream. One of these near Tapli was measured by Mr. Wynne (Records, XII, p. 132) and found to be 109 feet in girth, and others of about half that size are pretty frequent lower down. *None of these have descended the Dohr*, and at first sight the impression was a very strong one that the seeming bank on which Barukot stands, littered over as it is with 'erratics,' was a moraine which had descended the Siran valley and been breached by the Dohr prior to its effecting a junction with the former river. An examination of the ground about Barukot, however, totally dispelled this view and revealed a very curious and anomalous condition of things. The ridge in question was found to be a remnant of the same old alluvium constituting the Haripur plain, and cut into a tongue by the Siran on one side of it and the Dohr on the other. This spit, or tongue, is thickly covered with Indus *boulder gravel* and some *erratics;* but not a single erratic or boulder encroaches on or is found in the Haripur plain, which is here below it in level; and I do not think any of this gravel is discernible over 100 yards beyond its sharply-defined boundary at the village of Dari, or south of the Dohr, which ran under the Barukot ridge.

In the valley of the Siran, not a boulder or erratic is to be seen, and the surprising inference is unavoidable that the capping of boulder gravels and erratics has been washed over the Haripur alluvium from the Indus itself. At first sight it would seem as if these erratics and boulder gravel or drift must have *ascended* the course of the joint Dohr and Siran valley, but a glance at the map and the space covered by these 'erratics' will show that supposition is not necessary. But

the remarkable thing is, that if the Indus current brought this gravel over the top of what now form the Barukot ridge, it did not pass bodily round Gandgarh hills and flow through the plains east of Gandgarh.

The accumulation of 'erratics' rafted by ice, up a backwater of a tributary during a flood in the main river, could be easily understood; but not so a thick deposit of boulder gravel, unless on the supposition that the well-rounded character of the boulders is no bar to their being a veritable glacial deposit also. And this conclusion is, I think, the only one admissible. A strong current alone (if we dismiss the idea of ice flotation) could have accumulated the coarse cap of boulder gravel and clays here seen, between Dari and Barukot; but if the Indus flowed as far as Dari in full current, it must have flowed further towards Haripur; but this it unquestionably never did, and the conclusion therefore is that this deposit is one formed by floating ice charged with clay and boulders, which accumulated in the 'cul de sac' of the Dohr mouth and deposited its burden on melting all over the area submerged by the Indus flood water. The reason why the Indus did not flow further into the Haripur plain is of course that the plain was then higher than now, and barred the further advance of the flood waters laden with 'erratics' in that direction. As I have remarked, the boundary of this coarse boulder deposit is very sharp and defined, and this belt of gravel has served to check denudation over the area covered by it, while the undefended alluvium of the Haripur plain has been greatly lowered by the scour of the Dohr and its feeders, the result being the scarped gravel-capped ridge on which Barukot stands. Parts of this deposit have a certain resemblance to the *Talchir boulder bed*, in consisting of a compact clay in which boulders are disseminated, as may be seen in the cuttings on the Torbela road, though the bulk of the deposit is a coarse stratified boulder gravel.

The following localities for 'erratics' may be specified. From Barukot to Torbela along the course of the Dohr, and on the left bank of the Indus for some miles above Torbela, some of these gneiss erratics are over 100 feet in girth. Near Attock small erratics, as well as rounded boulders, are freely scattered about to a level of from 300 (or perhaps 400) feet, or thereabouts, above the present bed of the river. South of Háji Shah a gneiss 'erratic,' some 20 feet in girth, is lying in a field, and some smaller ones near it. One mile north-east of Campbellpur is a gneiss 'erratic' 30 feet in girth, and in the low ground near Campbellpur, an enormous number of 'erratics' from 20 to 30 up to near 100 feet in girth. The largest of these are limestone, but some of the smaller ones are of gneiss. South-east of Campbellpur, near the village of Boliwála, a little outside, seemingly, the limits of the Indus bed, or Haro (Hurroh) channel as it now is, a few 'erratics' are seen 12 feet or more in girth; and these blocks were probably stranded there during floods. At 1½ mile east-south-east from Boliwála is a granite 'erratic' in a field by itself, with 'cup marks' on the top.

The whole country in this direction, towards Kala-ka-serai, is an old high level alluvium, co-extensive with the Indus alluvium of the lower Haro (Hurroh) valley, but no erratics save those near Boliwála on its edge were noticed in it. Some 3 miles north-east of Choi, on the road from Campbellpur, a huge and jagged erratic of quartzose gneiss occurs. It has spontaneously broken up into

several pieces, but must when whole have measured some 60 feet in girth. In a word, the whole country is dotted with these erratics from the point where the Peshawar road crosses the Haro, to the mouth of that river at Barotha, and thence to Dakner in the Attock road.

Across the Indus, in a north-west direction, stretches the Yusufzai plain, the broad open valley of the lower portion of the Kabul river. This plain consists of a thick deposit of alluvium laid down by the Kabul river and its tributaries, and may be partly at least of lacustrine origin. I made one traverse across it from Nowshera to Hoti Murdán. Opposite Nowshera is a low range, over which the road is carried. To the right the range sinks down and is covered over by alluvium. Resting on this alluvium, were a good many large limestone blocks, which seemed to have travelled from the neighbouring range, rafted as I imagine by ice. A little west of the road, on the slopes of the range, I noticed a large block of limestone "perched" on three smaller blocks on the alluvium. These blocks had none of the appearance of being artificially arranged, and if not, this must be considered a truly '*perched*' block. None of these blocks exceed 6 or 8 feet in diameter, and they are all derived from the ridge to the west of the road. I noticed no erratics along the line of road from Attock to Peshawar, and it is pretty certain the Indus 'erratics' never invaded the Yusufzai plain. This I at first thought strange, till I discovered that at the period of their transport, the Indus ran (as explained) far south of its present course and east of Attock to Barotha, which may help to account for no erratics being seen north of Attock, though no doubt the valley of the Kabul river will be found to have its own proper 'erratics' of the period when search is made for them.

The Pakli plain, or valley north of Mánsahra, and the Ughi plain to the north-west, both present the same general feature; they are both surrounded by hills, the former being traversed by the Siran river, the latter by the Ughi river, falling into the Indus near Derband. In the Pakli valley the alluvium of the Siran river is some 300 feet thick or thereabouts, of which an excellent section is seen on the road from Mánsahra to either Ughi or Shinkiári. No 'erratics' are seen in the valley gravels, which are simply ordinary river gravels and clays interstratified; but large boulders, which I regard as erratics, are occasionally seen, strewed over the surface. In the open part of the valley these blocks are exceptional; but a few miles from Shinkiári, where the Siran debouches from the hills, and all up the Siran valley, below and above Shinkiári, erratic blocks are very numerous at all levels resting on the surface of the ground.

I have not examined the Ughi plain in detail, but at the foot of the Susalgali pass leading from Mansahra to Ughi, and a few miles from that place, I noticed a few granite blocks resting on the alluvium, precisely as noticed near Shinkiári.

It is, however, in the valley of the Nainsukh or Kanhar river that the clearest sections are seen demonstrating the relations of the 'erratics' of the glacial period to the older alluvial deposits.

The Nainsukh falls into the Jhelum opposite Rara, and at Gurhi-Habibulla on the direct road from Mánsahra to Muzafarábád, is a muddy brawling glacier stream, spanned by a handsome suspension bridge. In the bed of the stream

are numerous 'erratics,' and I determined to trace them to their source, though I hardly anticipated so clear and decisive a result as rewarded my efforts.

The valley of the Nainsukh or Kanhar river, draining the Kaghán valley on the north, is very narrow with a very great fall, and bounded on either side by ranges of hills with peaks from 8,000 to 15,000 feet or more. On nearing Garhi Habibulla from Mánsahra enormous 'fans' are seen descending from the range across the river (to the east) to the stream. On the west bank, however, the road from Garhi to Kaghán lies along the bed of the stream, and is skirted in many places for miles by a steep cliff of old river gravels, through which the brawling river has cut its present bed. This cliff varies from 80 to 100 feet or more in height, and the thickness of the gravels, or old alluvial deposits, of the Kanhar river may be 150 or 200 feet or more, which is neither easy on a cursory visit, nor material to determine. In this cliff every pebble is clearly exposed, and the striking fact was soon established beyond all question, that no 'erratics' existed in this deposit from top to bottom. Yet, they were plentiful enough in the bed of the stream, from 15 to 60 feet or more in girth.

Where, then, did they come from?

About Garhi, the gravel of this old alluvium is not very coarse, that is, it is a gravel in which boulders of one foot in diameter are rare and conspicuous for their size, contrasted with the bulk of the materials around them. Ascending the stream, however, the deposit increases in coarseness gradually, till near Byssia, boulders of from 1 to 10 feet in diameter have become pretty numerous, but no erratics or boulders of a larger size. The section of the deposit is clear, and the fact indisputable. A mile below Byssia, the road winds round an almost overhanging cliff of these gravels. Here an occasional boulder of 3 feet in diameter may be detected, though such are rare; whilst in the river bed beneath huge 'erratics' are plentiful, and a little way higher up numbers occur, two of which were over 70 feet in girth. The largest 'erratics' in the river bed are of the usual Hazára gneiss; whereas gneiss is not prominent in the terrace gravels, and only in small boulders, the larger blocks in these beds consisting of limestone, hard schists, or trap rocks. It, therefore, became perfectly clear, even before reaching Byssia, that no erratics were being brought down by *any* agency during the period these old gravels were being laid down.

This deduction, which is beyond challenge, is the key to the glacial phenomena of the entire sub-Himalayan region.

Byssia is built on a low terrace of coarse gravel, as described above; but it is not more than a third as high as the terrace near Garhi. On the opposite bank of the river, however, a part of the old alluvial terrace is seen of the usual height, so it is clear that *some agency* has operated to reduce the height of that portion on which Byssia stands. Close to the village some scattered 'erratics' are seen, and at the village graves, a line of erratics commences and extends thence right up the valley. The annexed sketch (see map) will illustrate the general feature of the ground. The erratic blocks are of the ordinary character of the Hazára gneiss erratics; and it would seem to be the continuation of this line, engulphed in the river, which I noticed above as yielding blocks 70 feet in girth.

The origin of this stream of 'erratics' is not far to seek. Ascending the valley above Byssia, the village of Shahwal is soon reached, standing on the further bank of a small stream. Down this stream has descended what those who please may call a 'fan,' but what I term a 'moraine,' disintegrated perhaps by subsequent stream action, but which consists of an enormous stream of granite blocks from the range behind, up, say, to 40 feet or more in girth. This stream unites with a similar one which has descended the main valley, and is just an old lateral moraine. A little way below this a small streamlet of blocks has forced its way down a narrow valley,—I may almost say cascaded down it,—and joining the larger lateral moraine of Shahwal has helped to swell the stream of blocks all tending towards Byssia. The little valley alluded to is barely 50 yards broad with steep V sides, and yet several of the blocks piled all on top of each other are from 40 to 70 feet in girth and completely jam the gorge. The fall of this gorge is steep, and I doubt if it ever contains a couple of feet of water, and that must be often broken up into foam, cascading over these rocky masses, the arrangement of which is shown in the outline section, fig. 2 (see map).

In bringing forward this section, however, I claim to be understood intelligently, and not to be confronted by inapplicable syllogisms of the well-known V order of argument of the antiglacialists. Whoever, indeed, looks here for ice marks on the rocks will be disappointed; nor can the obvious history of the gorge lead to any other anticipation. The gorge originally gave passage to a small glacier, as no other means I consider adequate to the transport of the rocky masses found in it. The base of the glacier no doubt was of the usual shape, and at a much higher level than the present bed of the V-shaped gorge. On the disappearance of the glacier, stream action commenced, and, aided by the scour of the sharp granite detritus, soon effaced the old valley and cut down the present V-shaped channel into which, *pari passu*, the 'erratic' blocks subsided. To imagine that such a piddling stream as could ever have found its way down here, brought down these huge blocks, is simply absurd. The argument might be adduced for the large stream under Shahwal, but not here.

The constitution, however, of the old river gravels disproves the idea that stream action which produced them had any influence in bringing down the 'erratics.' The material of which the 'erratics' consist, existed then, as now, close at hand in the adjoining ranges, but the *power* to move them was wanting, till the supervention of glacial conditions during a later period. It would be mere repetition to describe similar cases all up the valley, the 'erratics' everywhere reposing on the river gravels and being obviously referrible to subsequent ice action and not to river transport.

The consideration of the above facts affords a key, in my opinion, for reconciling the opposing views held, regarding the share played by ice in the formation of these recent deposits. The presence of huge 'erratics' strewn over the outer hills is appealed to by men like myself, supporters of glacial views, as a proof of the reality of such agency, and is opposed by other observers on the ground that such blocks are embedded in deposits of palpably fluviatile origin, but *till now* it has never been shown that both advocates are in a measure right, though in reality the erratic blocks merely rest on and are not really embedded, save

superficially, in the river deposits. To quote an example: Near Riási, on the Chináb, an enormous limestone 'erratic' was pointed out by me to my colleagues, Messrs. Medlicott and Lydekker, in proof of glacial conditions having necessarily been involved in its transport, but as it *rested on* a thick deposit of river gravels, my argument was held to be discredited. In these cases, *as in all others that I have seen*, this 'erratic' block rested on the river deposits, but the true significance of this fact was not then fully comprehended by any of us, and was looked on as fortuitous, in place of being the normal position of these blocks with reference to the old river gravels.

Considering then, as I do, that the distinct relation of a newer glacial deposit, consisting mainly of 'erratic' blocks, to an older fluviatile deposit, as established beyond controversy by the sections seen in the Kanhar river, and the consequent extension of an isothermal line compatible with the existence of glaciers, to so low a level as between 2,000 and 3,000 feet in the Northern Punjab, I would here add a few words on the various objections which have been adduced against the possibility of such a condition of things elsewhere.

In my paper on the ancient glaciers of the Kángra district (Records VII, p. 86), I endeavoured to show that the 'erratics' originally described by Mr. Medlicott as 'glacial debris of the Dhauladhár' (Memoirs, III, Part 2, p. 155) were really due to moraine transport; but I did not then comprehend the true key of their seeming anomalous relation to fluviatile deposits wherever they are seen to rest. I did not then apprehend that they only rested on such deposits and were not enveloped in them. But I *did comprehend and claim to have distinctly asserted that they were of moraine origin, and, what is more, that there should be no possible misapprehension* (though in this I was vastly mistaken), I divided the area into three vertical zones or areas, naming each respectively pre-glacial, glacial, and post-glacial. I quote my own words (*l. c.* p. 93). "The Kángra district may be ideally divided into three vertical areas or zones:

Firstly, a pre-glacial area embracing the whole country, which contributed from peak to plain to the *genesis*, and development of the glaciers under consideration; speaking roundly and without any measured data to check the estimate, the above zone or area embraces all ground higher than from 250 to 300 feet above the mean level of the present streams.

Secondly, a glacial area proper, embracing the entire area either occupied or excavated by the glaciers, which may be approximately fixed as commencing at the bottom of the above division and terminating below, at a level of about 150 feet more or less above the mean level of the present streams.

Thirdly, a post-glacial area, embracing the whole of the ground below the basal limit of the last division and the result of aerial denudation subsequent to the cessation of glacial conditions."

The precise figures used are, of course, open to correction, but no possible exegesis can render the above words *clearer than they are*, as they stand, and yet Mr. J. F. Campbell, F.G.S., with my paper in his hand, actually potters about, looking for glacial markings within my *post-glacial area*, and finding none, pronounced my theory discredited (see Journal, Asiatic Society of Bengal,

Vol. XLVI, Part II, 1877, Campbell on Himalayan glaciation). I shall not discuss Mr. Campbell's brochure at length, simply because a man who professes to refute the views of another, which his every word proves him not to have comprehended, cannot be profitably argued with, but some of Mr. Campbell's arguments, being of a general nature and the joint property and stock-in-trade of all anti-glacial geologists, may be here noticed. It may be here mentioned that as Mr. Campbell has not realised the conditions which I believe really obtained, many of the arguments adduced are really and truly beside the question; but " n'importe."[1]

Arguments why glaciers never descended, as ascribed by me, to within 2,000 or 3,000 feet of the sea in Northern India:—

I.—The course of these suppositive glaciers lies along V-shaped valleys, which indicate aqueous, not glacial, erosion.

Undoubtedly, as the remarks previously made show, the glaciers descended *on top of an enormous accumulation of gravels filling up the old valleys of a V shape.* These gravels were only partly cut down and cleared away by the glaciers; and partly to this, and partly to the post-glacial action of streams, the contours of the ground are all of the V kind. Argument No. I is consequently worthless.

II.—No glacial markings are found on rocks *in situ*, as must have been the case had each river bed given passage to a glacier, as asserted.

To this I remark, that search for such marks seems generally to have been made by Mr. Campbell in places where, if my theory is correct, no glacier ever descended, that is, in contact with the present rock surface; and that the ordinary roads leading up our large river valleys lie, as a matter of fact, below the level, where ice action would have left its mark. Then, again, so much of the ground in question is made up of rock unfitted for, or incapable of, retaining 'ice markings;' and when the rock *is* fitted, it forms crags above the paths now used, accessible to few living things, save the wild goat and his natural enemy, the human hunter. This argument is therefore no better than the last.

III.—Absence of striated blocks within the area asserted to have been traversed by glaciers.

To this I reply that the rock which has furnished the largest and most numerous 'erratics' (granitoid gneiss) is wholly unfitted for the retention of any

[1] Mr. Campbell's observation was very far from being so preposterous as Mr. Theobald would make out. Notwithstanding the definitions quoted above—a general meaning for which (and it would be ridiculous to attach a rigorous meaning to such definitions, where the conditions necessarily admit of exceptions) was sufficiently obvious, in the prevailing erosion of the river gorges below the level of the old gravels—it was a perfectly fair, or even inevitable, inference that any rock-surface supporting the old gravels was one on which, according to Mr. Theobald, a glacier had travelled. Mr. Campbell found such a surface freshly exposed, but without any trace of the markings required by such conditions. There might remain a dispute about the identity of the gravels at that spot, but this would altogether change the venue of the case. It would seem that Mr. Theobald did not at the time comprehend his own brochure otherwise than Mr. Campbell; for in a subsequent notice (Records X, p. 140) of the opinion that had been passed upon the supposed glaciers of the Kángra valley, he makes no allusion to the rejoinder which he now (as suggested by his recent observations) urges with such ultra ferocious vigour—a triumphant style which by no means helps to impart the conviction it ostensibly implies.—H. B. M.

such marks; and also that the deposits, whereon *these erratics rest*, being of fluviatile origin, have naturally been searched in vain for such evidence; and lastly (whatever may be the reason therefor), in India, scratched blocks are so rare as almost to be exceptional in the vicinity of existing glaciers. The absence or rarity of 'scratched blocks' at low levels is merely, therefore, a negative argument, which, if of any force, might be used to disprove the existence of glaciers, where they are now actually to be met with. Argument No. III therefore is as little cogent as its predecessors.

IV.—Water power is sufficient to account for the transport of the blocks termed by me 'erratics' and referred by me to either floating ice or 'moraines.'

This is an argument which anti-glacialists never weary of producing, in season and out of season, and requires therefore some consideration. As the Kangra 'erratics' range up to 150 feet in girth, and many of them of very large size stand well out in the plains, away from the hills and in cultivated ground, I have no belief in such a vehicle for such blocks. How the case might be in a river bed is another matter; but standing, as many of these erratics do, in open ground, the idea is not tenable for an instant.[1]

Mr. Campbell remarks: "I am quite certain that the Kángra erratics are large 'pebbles' washed out of the 'cads'[2] by heavy floods." Now, if these erratics were met with *only* in the 'cads' (khuds) or more numerously in the khuds, than out of them, Mr. Campbell's argument would have a colourable basis; but the reverse is the case, and the largest blocks are found in spots where it is impossible they could have been washed into out of any possible khud.

To descend, however, from the general to the particular. Let us examine the case of how Indian rivers do deal with masses, such as Kángra 'erratics.'

In my Kángra paper I say: "At Sujánpur, the moraine of the Sujánpur glacier is seen pushed right across the present channel of the Beas, at a *much higher level* than that of the present stream, which has made a clean and deep cut through it; yet, though the 'erratic' blocks scattered round the travellers' bungalow at Sujánpur and all over the truncated end of the moraine on the opposite side of the river are of a large size, not a trace of one can be seen in the river bed beneath."

This disappearance of the 'erratics' in the bed of the stream may be accounted for in three ways. There is, first, the 'rush of water' theory of the anti-glacialists, and, doubtless, if a piddling stream could have brought these blocks as far as the banks of the Beas, the bigger river could have easily moved them on; in which case we should expect to find them congregated in a lump or bar, at the first spot where the reduced velocity of the river outside the hills deprived it of the

[1] The fallacy of assuming that the surface on which these blocks now lie is that on which they were deposited, has been already indicated (Jour. As. Soc., Bengal, XLVI, Pt. II, p. 12).—H. B. M.

[2] I am indebted to Mr. Medlicott for kindly pointing out to me that the word 'cad' which I had (in my ignorance) supposed to be a local term, current in the Highlands of Scotland, and pure Gaelic for gravels, was merely a novel mode of spelling the common Indian word 'khud' = a steep valley.

necessary power required to carry the block onwards; but no such accumulation is seen, and hence it is very doubtful if the river ever acted in this manner. Secondly, the blocks, after being engulphed in the main channel, may be supposed to have been destroyed by wear and tear and the impact of rolling masses during floods. Such a process, no doubt, disposes of a vast bulk of materials in every stream; but it is a process probably more active in mountain torrents with a steeper fall, but less actual body of water than the Beas. Thirdly, there is the scouring action, which during floods undermines big obstacles to the current, and eventually entombs them in the grave thus produced, levelling the gravel flush over the spot where they have disappeared; and this I believe to be the case in the Beas, and the true explanation of the paucity of 'erratics' in its channel.

To consider now the case of a river whose velocity largely exceeds that of the Beas at Sujánpur. The Jhelum below Uri fulfils this condition, as the stream is there in many spots a 'race,' and the bed of the river is full, moreover, of these very erratics, derived from the lofty peaks of the Káj Nág adjoining. What water can do in a stream bed with such 'erratics' we here see. The effect of the rapid stream is to clear away all gravel and smaller boulders, leaving the larger masses packed against each other, with great cavernous interspaces between. Over these masses of rock, the waters cascade in sheets of foam, or force their way in hissing jets between or beneath them; but the rocky masses themselves are immoveably packed by the very force and agency of that element which some would regard as capable under such circumstances of sweeping them away. Not a bit of it—occasionally a blasted pine, whirling down stream, gets swept between the blocks, and by its leverage wrenches them apart; but this is a passing incident, and its effect, so far as any onward and progressive movement of the blocks is concerned, is inappreciable.

These two instances of the Beas and Jhelum illustrate the power possessed by water under the ordinary operations of nature to move masses like the sub-Himalayan erratics; but the necessity of weighing the argument is almost dispensed with from the now established fact (presuming the Kángra and Hazára deposits to be homologous) that the erratics do not occur embedded in the old river gravels, but simply resting on them.

How, too, I ask, on the supposition advocated by Mr. Campbell, that the '*erratics*,' as I consider them, are merely masses transported down a 'fan' by stream action—how, I ask, comes it, that they have crossed over the Beas from north to south, as shown in my map above Sujánpur. It is impossible that the materials swept into a river down a 'fan' should cross its channel and be found on the opposite bank. With the old glaciers the case was different. They coincided generally only with the present valleys, but not with the existing river beds; and hence, as in the case of the 'erratics' on the south bank of the Beas at Sujánpur, their moraines were breached by the rivers which succeeded them. The same argument and the same latitude will not apply to any supposed rivers, as agents in producing this arrangement of 'erratics;' as, supposing the Beas (as is a simple supposition, quite possible) to have formerly held the more southern course, which I suppose the glacier here did, and to have run south of where the 'erratics' in question now occur, yet it is impossible to suppose that the river

can have cut its way back north into its present course without removing, in so doing, the 'erratics' which stand in a position which would, under such circumstances, have been its channel for a certain period. The contour of the ground, too, is opposed to the idea of the river having ever flowed, at the spot, more to the south, so that the 'fan' theory of 'erratic' transport wholly breaks down.

The following notes, penned so far back as 1871, may be here quoted, as the views then advocated are strongly corroborated by the foregoing results of last season.

"The interest which attaches to any well-defined traces of former glacial conditions, away from the immediate vicinity of the main Himalayan ranges, induces me to bring forward such an instance (as I believe it to be) on the flank of Jogi Tillah, the well-known hill near Jhelum, and which must, if substantiated, offer considerable support to the view of a former more extensive glaciation in India than is generally supposed, and not dependent on any present local features, orographical or hypsometrical.

"Jogi Tillah, which rises somewhat abruptly from the plains, is situated 16 miles west-south-west from Jhelum, and may be regarded as the most easterly termination of the Salt-range, though severed from it by some complicated faulting and the channel of the Búnhar river. The mountain itself is a wedge of rock forming an epitome of the Salt-range strata, and displaying at base the devonian salt marl on the one hand, whilst on its opposite slope a thin belt of nummulitic limestone dips at a steep angle beneath the extended newer tertiaries which form the great Potowar plateau. As the dip of the beds is to the north-west, the scarp of the hill faces the south-east, and below the scarp, the hill side falls rapidly away over a talus of fragmentary blocks deeply excavated by ravines which furrow the newer tertiary beds at its base. Viewed from a distance, the profile of the outer hills immediately beyond the scarp of the mountain is peculiar, the outline being that of a long, flat hill, with a slope outward of less than 10,° though what is seen is really the profile of one of many long ridges, separated by narrow valleys, deeply excavated in the soft tertiary sands and clays. So far there is nothing peculiar, nor are any (at least prominent) traces of glacial action met with either to the east or west of the hill, or over the flat Potowar plateau stretching away for *miles to the* north of it. For a narrow space, however, of about 3 miles west of Hún, over a belt of ground corresponding with the loftiest point of the mountain, the whole surface is more or less thickly covered with blocks, irregular and sub-angular, of the rocks forming the mass of the hill and presenting all the appearance of having formed part of an enormous moraine, or group of moraines, which swept down with a grand curve a little west of Hamula, and thence on to within a similar distance of Hún, both villages standing just outside of the great stream of fragments. On the top of the ridges, now some 200 feet or more above the present streams, these fragments are thickly packed, but they are also seen strewed over the sides of the hill and choking up the beds of the streams. The general relations and arrangement of these blocks are

nowhere better seen than on the road from Hún to Hamula, and just where the road reaches the small stream west of the latter village, the whole country betrays signs of being littered over with moraine debris, though all, if I mistake not, subsided through their gravity and the gradually washing away of the soft tertiary beds whereon they once rested, and not actually *in situ*. This is clearly seen by tracing the blocks up the steep slope of the hill to their undisturbed place at the top, the top being the long sloping ridge, seen in all distant views of the ground as gradually sloping from the base of the scarped side of the mountain.

"On the top, then, only, of these ridges (no doubt once an extended and continuous plateau) the undisturbed moraine materials are seen, but beyond, on the lower ground, and on the sides of the hills, the materials are distributed, under the influence of ordinary denudation and gravity.

"The blocks which form this great flood of stones are irregular in shape and sub-angular, of no very great size, 2 feet in diameter, perhaps being a fair mean, though some larger ones are interspersed here and there. The largest remarked by me was barely 8 feet in length, and was split into three pieces, where it lay, most probably, by the action of frost, to which may be attributed the absence of any large fragments. The majority of blocks consisted of the magnesian limestone, or some of the sandstones found in the hill; but the red sandstone, overlying the salt marl, though not absent, was scarce, and the few specimens seen were much decayed from the joint action of saline infiltration and the consequent disintegration of the stone through the action of moisture and frost.

"That these stones all descended from the scarp of Jogi Tillah is clear, but *how* is the question. The ground covered by these blocks may be roughly taken as some 3 miles in breadth opposite the highest peaks of Jogi Tillah, whilst the flood of stones extends over 3 miles or more from the highest peaks. Now the horizontal catchment area opposite the highest scarp is not appreciably greater than on an equal breadth opposite the less elevated portions of the mountain, so that had mere streams been the motive power, we should have to account for a local debacle of stones for which no adequate explanation through local stream action was available; whereas in the case of a glacier, it is clear that the magnitude of the associated moraine would bear a more or less close ratio to the altitude of the rocky face from which the glacier originated, just such a relation, in fact, as these scattered masses display with relation to the highest point of the mountain.

"Three miles may seem a distance not too great for these blocks to have travelled during the countless centuries during which the streams have been lowering their channels from the old high level at which they once ran—the old glacier level in fact; but such a supposition leaves out of sight two points: first, that though such small streams as descend from Jogi Tillah are capable of a very powerful erosive action on the soft beds through which they run, their direct transporting power forwards as regards large subangular masses of stone is almost *nil;* and, secondly, that the great bulk of debris, which I term a 'moraine,' is certainly transported, and that a clear distinction can be observed between the high level bulk of the deposit, which may be regarded as the material

as left, *in situ*, by the cessation of the transporting cause, and the subsidiary effect of stream cutting which has since been going on, allowing the lapse from the higher level of the "moraine" matters by simple gravity into the newer and ever-deepening channels. There is thus a "consensus" of arguments all tending to support a glacial origin for the blocks in question.

"There is the general appearance so suggestive of a moraine in the arrangement of the coarse materials, and the marked and definite sweep they assume west of Hún and Hamula. Then there is the marked relation of this band of debris to the highest part of the hill, which might of course call for no remark if it was confined to a mere talus along the base of the mountain, but is very significant when it is found stretching outward at a high level in a manner hardly compatible with mere fluvial agency, and there is the difficulty of admitting the power of streams to produce such a result under the peculiar physical and surface conditions of the neighbourhood. Finally, it can hardly be questioned that Jogi Tillah lies well within the isothermal limits of former glacier extension, since I have shown that at the period in question that line embraced the southern flanks of the outer hills down to the plains west of the Jumna."

The above extract from my notes is given with trivial verbal alterations, precisely as it was written in 1871; indeed there is no call for any alteration. Both Mr. Medlicott and Mr. Lydekker accompanied me over the ground, and they were much struck with the appearances which I refer to glacial conditions, though I believe their verdict at the time was one of 'not proven.' It was then certainly more bold to adduce such a cause than it would be now, after so convincing a demonstration of glacial agency at low levels has been made out; but I had previously discovered symptoms of glacial influences to the east, which, if not conclusive *per se*, had their proper weight in determining my own conclusions. I will mention a few—not that I insist in every instance that they are absolutely indications of glacial agency, but that such agency seems the most probable explanation thereof, and, with a view to direct future observers to these obscure features, that their true bearing may be better elucidated. In the northern part of the Jhelum district, in the vicinity of the Jhelum river, a noteworthy feature in the landscape is the presence of flat, high level plateaux. These are but thinly covered by surface alluvium, and are not portions of old lake beds, but consist of sandstones with various dip planed down flat in a manner which makes it difficult to refer such to the result of wandering stream action. These flat plateaux are sometimes slightly inclined, and the most natural explanation of this particular surface configuration is 'ice action.' It is a feature I have nowhere seen noticed or alluded to by previous writers, and I consider it one which merits further study.

The occurrence in the valleys of moraine materials, disposed as I have described in the Kunhar valley, I shall not here allude to at length, as such cases are rarely so clear as seen there, and I may have an opportunity of re-examining some spots where such deposits are in force, as in some tributaries of the Chináb. I will, however, mention one case of a transported block which I think can be due to none save glacial agency. It is a limestone block lying on the stream, 12 miles south-west from Riási, on the Chináb, between the villages Bardol and

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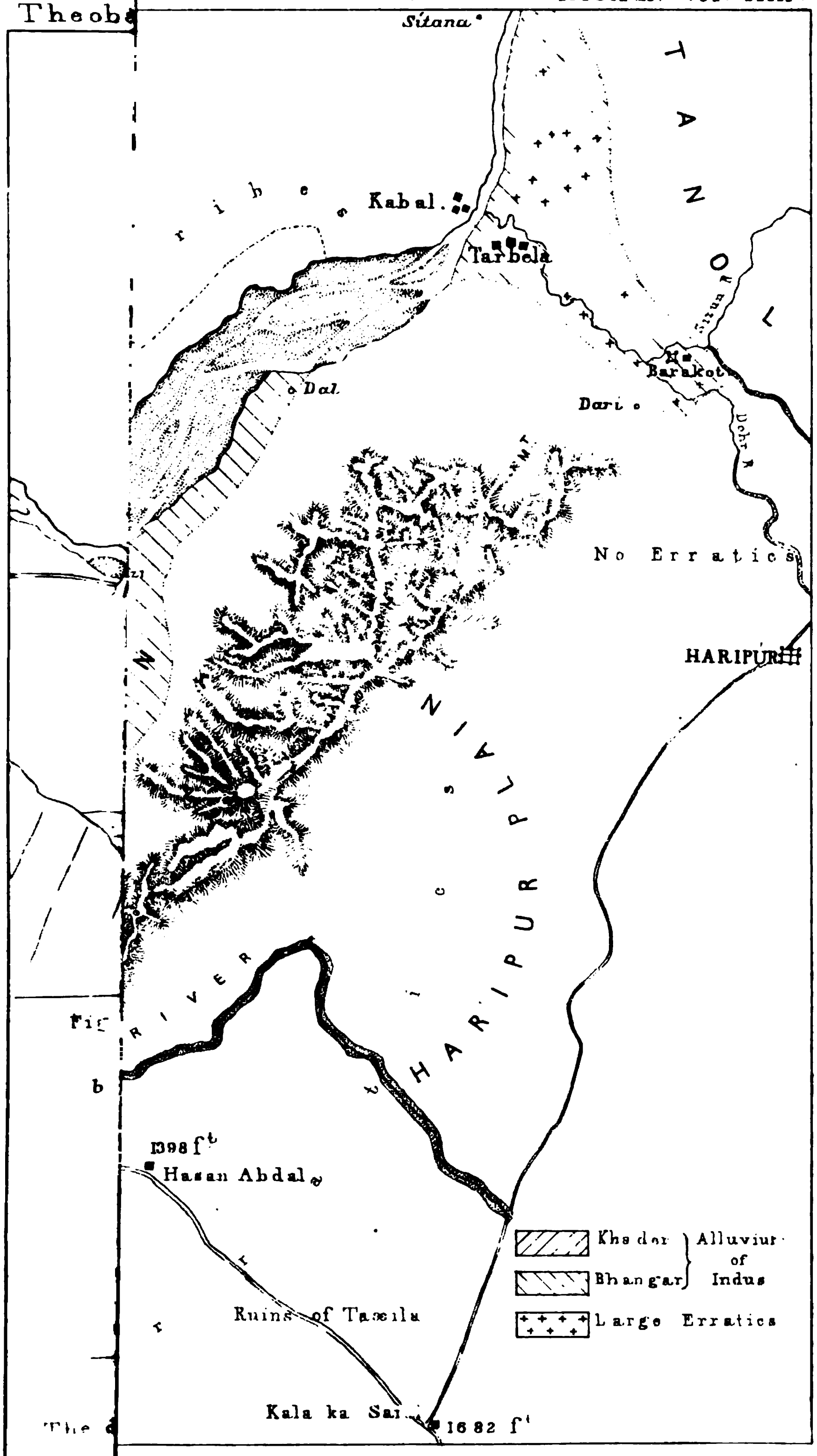

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Karkeli. This block of limestone has been derived from the limestone range to the north near Poni; but the entire drainage area within which it lies is composed of Siwalik sandstones, and it must have crossed the present watershed before the excavation of the existing valley. The Chináb here debouches from its rocky gorge into the more open valley below Riási, and flows through a very thick coarse boulder deposit, 4 miles broad and 8 miles in length, measured along the river, which deposits tail off, and rapidly diminish as we recede from the river, and are in my opinion largely composed of the re-arranged glacial materials which must have filled the Chináb valley at no remote date, and I refer the limestone block near Bardol to the same agency and period as that to which I attribute the erratic block previously mentioned as lying on the top of a thick river gravel near Riási. At Bardol, however, the block in question has subsided into the valley by the removal, by denudation, of the looser materials whereon it rested; whereas near Riási the other block is still resting in nearly its original position, on the undisturbed gravel at a high level above the river. No doubt numerous similar cases occur; but this one may be particularised, as there is no ambiguity regarding its position and relations.

USEFUL MINERALS OF THE ARVALI REGION *by* C. A. HACKET, *Geological Survey of India.*

Although the Arvali region does not abound in mineral wealth, still it contains several extensive mines from which, in bygone times, large quantities of copper and lead ores have been extracted, and a number of small pits or burrows where ores in small quantities were found.

None of these mines were worked deeper than a few feet below the water level on account of the difficulty of raising the water. In some cases, however, when the mine is situated on a hill, an adit level has been driven into the hill to drain the workings and cut the veins at a lower level in hope of finding richer deposits; but I believe, both in the case at Ajmere and Daribo, these hopes were not realised.

All these mines, with the exception of those worked for iron, are now abandoned, and the workings filled with water or fallen together, and so little is now seen that it is impossible to form an opinion of their value.

The ore occurs either in small discontinuous veins or thinly disseminated through the rocks. In no case is there anything like a continuous vein or lode exposed.

The following is a list of the minerals, and the localities where found:—

COPPER.

		Atlas sheet. No.
Singhána	Shaikhawáti, Jeypore	49
Khetri		
Daribo	South of Kho, Ulwar	50
„ in the ridge 1¼ miles to the west	... ...	50
Bhangarh	Ulwar	50

		Atlas sheet No.
Kushalgarh	Ulwar	50
Baghani	Do.	50
Partabgarh	Do.	50
West of Nabaro West of Udhala	Near Sainthal, Jeypore	50
South-east of Garh Lalsot	Lalsot hills, Jeypore	50
Babai	Shaikhawáti, Jeypore	50
Nithahar	Bhurtpore	50
Datunda	Boondee	34 S.E.
Rewara	Near Gangapur, Oodeypore	34 S.W.
Ajmere	Near the Jail	34 N.E.
Tasing	Mandan hills, Ulwar	50
Jasingpura	Near the railway, Ulwar	50
Gugra	4 miles north-north-east of Ajmere	34 N.E.
Rájgarh	10 miles south of Ajmere	34 N.E.
Rajauri	Near the above	34 N.E.

GALENA.

Táragarh hill	Ajmere	34 N.E.
Ganespura	30 miles south of Ajmere	34 N.E.
Indawás Gudha	Thana Ghazi, Ulwar	50

IRON.

Bhangarh Rájgarh	Ulwar	50
Karwar	Hindaun, Jeypore	50
Ajmere	Near the Jail	34 N.E.
Gangár	Oodeypore	35 S.E.
Bhairompura	Boondee	34 S.E.

NICKEL AND COBALT.

Bhangarh	Ulwar	50
Babai	Shaikhawáti, Jeypore	50

ZINC.

Jáwar	Oodeypore.	

RUTILE.

Motidongri ridge	Near Ulwar	50

PLUMBAGO.

Sohna	Gurgaon	49

GOLD.

Sohna	Gurgaon	49

KAOLIN.

		Atlas sheet No.
Kussumpura ...	... South of Delhi	49
Bachára ...	... Ulwar hills	50

GARNETS.

Sarwár ...	... 20 miles south-east of Nusseerabad	34 N.E.
Rájmahál ...	... Jeypore	34 N.E.
Meja ...	... Oodeypore	34 S.E.

ROCK CRYSTAL.

Aurangpur ...	... 15 miles south of Delhi	49

MARBLE.

Makrana ...	... Jodhpore	33 S.E.
Jheri ...	... Ulwar	50
Raialo (Raiwala) ...	... Jeypore	50
Sarangwa ...	... 6 miles west of Desuri, Oodeypore	34 S.W.

STEATITE.

Móra, Bhandári ...	... About 12 miles north of Hindaun, Jeypore ...	34 S.W.

The most extensive of these mines are those of Khetri and Singhana in Shaikhawáti, Daribo in Ulwar, and the lead mine at the base of the Táragarh hill near Ajmere. The rest are, comparatively, very small.

Copper.—That the old workings, both at Khetri and Singhana, were very extensive, and the quantity of ore raised considerable, is shown from the large and numerous heaps of slags resulting from the smelting of the copper ore. The hill on which the Singhana fort is built is formed, in a great part, of these slags.

The abandonment of the mines is attributed to the partial failure of the ore in depth and to the increased cost of working, and as the Jeypore Durbar would not reduce the royalties, the miners abandoned the mines and left the country. At present a few men make a living by picking out some stones of ore left in the old workings; and a number of people are engaged in the manufacture of Lila (blue vitriol), Pitkhera (alum), and Kasis (copperas).

The Khetri mines are situated a short distance north of the fort near the crest of a ridge of slates about 500 feet above the level of the plain. The mine is entered by several shafts of considerable depth, and which lead down to a gallery, said to be upwards of 2 miles in length. The direction of the level, as pointed out to me, appeared to be parallel to the strike of the slates. The ore now brought up from the old workings is copper pyrites; it occurs in small strings, and disseminated through the slates.

The Singhara mine is about 6 miles north of Khetri. It is entered by a wide gallery driven into a ridge of quartzite, in the same direction as the strike of the rocks, and near the top of the ridge several hundred feet above the level of the plain. This gallery is, in places, 40 to 50 yards wide and of a considerable

height. Its course into the hill is very irregular; the descent for the first hundred yards is slight; beyond this the gradient becomes steep, not less than 60°; judging from the extent of the excavation, a rich pocket of ore must have been met with. At this point three separate galleries extend into the hill somewhat oblique to each other.

Beyond the extent of the excavations very little is to be seen in these galleries, as hardly a spec of copper has been left by the old miners, and the ends are choked up by fallen debris or filled with water.

My guide through the mine had formerly leased it; and he acknowledged that the mine was abandoned from the failure of the ore in depth. But it is possible that in continuing the level southwards other pockets of ore would be met with. The mine is in a line with the Khetri mine, and it seems probable that many pockets of ore would be found if the intervening ground were explored.

Some time since, report says about a hundred years ago, the roof of the gallery for about 100 yards from the mouth fell in, and a vertical face of the quartzites has been left standing in which numerous thin strings and nests of ore are exposed.

I was told that this was the mode of occurrence of the ore in the mine. In the bottom of the gallery only a few traces of copper are to be seen, thus showing that these strings or small veins did not extend, at this place, to any depth through the quartzites.

Considerable quantities of blue vitriol (sulphate of copper), alum, and copperas (sulphate of iron), are now manufactured both at Khetri and Singhana from the decomposed slates and the refuse of the mines. The slates are steeped in water, which is afterwards evaporated in large iron vessels, when the blue vitriol is first crystallized out, afterwards the alum and lastly the copperas. Mr. Mallet found traces of nickel and cobalt in all three of these substances.

The blue vitriol is sold for		...	...	Rs.	14	per maund.
„ alum	„	...	...	„	4	„
„ copperas	„	...	...	Re.	1	„

The Babai workings are in a line with these two mines and on the same band of slates, about 8 miles south of Khetri. The workings consist of a few pits sunk in the hill side. A little copper is found disseminated through the slates, but I believe the pits are principally worked for Saita, or ore of cobalt, of which mention will presently be made.

The next mine of importance is that of Daribo, near Kho, in the Ulwar territory. The mine is situated in a sharp anticlinal bend in slates and quartzites. An adit level is driven into the hill through the slates in a southerly direction parallel to the strike of the rocks. I could see no trace of a lode; the ore appears to be irregularly disseminated through the black slates, a few specs and stains only being seen in the quartzites. Where richer nests of the ore were met with, the miners have extended their workings a short distance above and below the level. The miners declare that a rich nest of ore occurs in a pit sunk below the level near its southern extremity, but it had to be abandoned on account of the water.

The present drift was, I believe, begun under the instructions of Captain Impey, formerly Political Agent at Ulwar, to drain the pits sunk by the natives in the hill side.

The copper occurs in the form of copper pyrites, mixed with arsenical iron. The mine is now nearly abandoned and but little ore is to be seen. I had some difficulty in finding a bit the size of a hazel nut.

Blue vitriol, alum, and copperas are manufactured at the mine.

I found traces of copper in some slates on the same geological horizon in the ridge a short distance west of Daribo.

The Bhangarh workings consist of two or three small pits now fallen together. The workings of Kushalgarh, Baghani, and Partábgarh have been abandoned for many years. The natives say that at the two latter places the workings were very extensive, and that the mine fell together suddenly, burying a large number of men.

A few small pits have been sunk in the quartzites west of Nabaro and west of Udhala, both near Sainthal in the Jeypore territory, from which a little copper ore may have been extracted, as the debris on the surface is stained with copper.

Near Lalsot, in Jeypore territory, a small hole has been made in the face of the scarp, and the stones about are stained with copper. At Garh, about 15 miles north-east of the above, a pit has been sunk to the depth of about 20 or 30 feet. There were traces of copper round the mouth of the pit. In both these cases, although the rocks surrounding the pits were bare and unbroken, I could find no trace of a vein or even of copper in any direction a yard from the pit's mouth.

At Nithahar, in the Bhurtpore territory, a short level has been driven into the hill and a small quantity of copper raised.

A small pit has been sunk in the quartzites about 2 miles east of Datunda in the Boondee territory. The stones are stained with copper, but I should not think sufficient was raised to pay the costs of the pit.

At Rewara, near Gangapur, in Oodeypore, a number of small pits are sunk in the schists in a north and south line for nearly a mile in length. These pits have all fallen together, or are filled with water. The copper appears to have been smelted on the spot, but judging from the small quantity of slags, no very large amount of ore was raised.

I observed traces of copper in the old iron workings near the jail at Ajmere, also at Tasing in the Mandan hills, and at Jasingpura near the railway, both in the Ulwar territory.

Captain C. J. Dixon, in a report dated 8th May 1835, published in the Journal of the Asiatic Society, Vol. IV, page 583, mentions the occurrence of copper ore at three localities near Ajmere, *viz.*, at Gúgra, 4 miles north-north-east of Ajmere, Rájgarh, 12 miles south-south-west of this, and at Rájauri, 10 miles south of Ajmere.

Galena.—The only lead mine of any importance occurs at the base of the Táragarh hill near Ajmere. Formerly these mines produced large quantities of lead, although there appears to be some discrepancy in the accounts as to the amount. Thus, Captain C. J. Dixon, in a paper ("Some account of the lead

mines of Ajmere") published in 1831 in Gleanings in Science, Vol., III, page 111, states: "The produce of the mines has hitherto been very limited. The annual quantity of metal smelted averages about 850 cwt.;" while it is stated in the *Ajmere Gazetteer*: "Mr. Wilder, the first Superintendent of Ajmere (in 1818), took the mines under direct management, and they produced annually from 10,000 to 12,000 maunds of lead, which was sold at Rs. 11 per maund.

"The Ajmere magazine was the chief customer, and on its ceasing to take metal in 1846 the mines were closed."

The mines consist of a number of pits sunk in a line several hundred yards long, extending from the hill to near the walls of the city. The ore occurs in a number of small roughly parallel veins running through a quartzite in nearly the same direction as the strike of the rocks. An adit level has also been driven into the hill, at a lower level, to drain these pits.

A small quantity of lead ore has been extracted from a pit sunk near Ganes-pura, about 30 miles south of Ajmere.

Some old lead workings occur at Indawas and Gudha, in Thana Ghazi, in the Ulwar territory. The former consists in a long open cutting from 20 to 30 feet deep, from which, apparently, a considerable quantity of ore has been raised. The workings are now filled with water. At the latter place a small pocket of ore was recently discovered, but which on being worked was found to die out in every direction.

Iron and Manganese.—Iron ore occurs in several localities, and some of the mines have been and are still extensively worked.

The mines of Bhangarh in Ulwar still produce large quantities of ore. These are now the only source of iron for the numerous furnaces in the Ulwar territory. The ore is a mixture of limonite, magnetite, and oxide of manganese, containing 59·67 per cent. of iron and 12·7 of manganese (Mr. Mallet's analysis).

The old and extensive mines near Rajgarh in Ulwar are not now worked.

Large quantities of a superior iron ore have been raised at Karwar, near Hindaun, but the workings are now abandoned, probably from the scarcity of fuel.

There are some old iron workings near the jail at Ajmere, but the produce must have been very small.

Iron ore is now worked to some extent near Gangar, in Oodeypore, and near Bhairompura, in Boondee.

Nickel and Cobalt.—Traces of nickel have been found in some of the iron ores from Bhangarh, but the pit from which the ore was taken has fallen together.

An ore of cobalt called *saita* (or *sehta*) is found in the slate hills near Babai in fine strings, and sparsely disseminated through the slates, with pyrrhotite (magnetic iron pyrites) and copper pyrites. It is described in mineralogical works as Syepoorite (probably a mistake for Jyepoorite), sulphuret of cobalt (sulphur 36·36, cobalt 64·64). The ore is used for colouring enamels, bangles, &c., of a blue colour.

Zinc.—Large quantities are said to have been obtained from Jawar, in Oodeypore, but as yet my examination of the country has not extended so far south as this.

Rutile.—Rutile (titanic acid) exists in small quantities in some little quartz veins in the Motidongri ridge a short distance south of Ulwar.

Plumbago.—At the back of the town of Sohna, in the Gurgaon district, a thin irregular band of schists occurs in quartzites. From these schists some specimens of plumbago have been taken. There are no traces of any excavations ever having been made, except a very small pit, which could not have been many feet deep. Anything that I could see was exceedingly poor, and hardly deserved the name of plumbago, and I doubt if any much richer was ever taken from this locality. A specimen sent to me by the Deputy Commissioner was as poor as those I picked up.

Gold.—When examining these schists, the Sohna Lumbadár told me that after every rains small quantities of gold were extracted from the sand, mud, &c., of the little water-courses at the bottom of the hill. I questioned the Chumárs of the town, who told me that it was true that they made a few rupees every year in this way, and that the heavier the rains, the larger the amount of gold. Last year, for instance (1877), as the rains were so slight, they did not get any, or did not think it worth while looking for.

The only rocks exposed in the gully are the quartzites and the schists. As it is not probable that the gold would be washed out of the hard quartzites, it must, I presume, come from the schists.

Kaolin.—The kaolin mines are situated at Kussoompur, and a short distance to south, in the Delhi hills, a few miles north of the Kutub Minár. There is only one mine now worked, and that, unfortunately, had not yet been opened for the season, so that I could only judge from surface appearances.

There are few small pits sunk in a hollow entirely surrounded by quartzites. The stuff brought out of the pits resembles, in every particular, components of the numerous granite dykes in the Arvali series, only the felspar in this case is decomposed. The plates of mica and crystals of quartz are mixed up with the kaolin in exactly the same way as they are with the white felspar in the granite veins.

This decomposed rock is thrown into water, when the mica and quartz are separated from the kaolin, and the latter made into small cakes and used for white-washing purposes, and as fire-clay.

Another kaolin mine occurs at Buchara, near the Lota river, in the Ulwar hills. There are numerous granitic veins near, and of course this kaolin is the result of the decomposition of the granite.

Garnets.—The Arvali schists frequently contain innumerable garnets, but it is not often that they are of sufficient size to be worth picking up. There are, however, extensive workings for them at Sarwar, 20 miles south-east of Nusseerabad, at Rájmahál in Jeypore, and at Maga in Oodeypore.

The Sarwar workings consist of a number of pits sunk in a narrow belt of mica schists, in which numerous granitic intrusions occur. The whole length (upwards of a mile) of the outcrop of the schists is burrowed in search of the garnets. Those I saw from the mine were of good colour and size, but badly cut.

The workings at Rájmahál and Maga are not quite so extensive; but they occur on the same geological horizon and were conducted in the same manner.

All of these workings are now abandoned.

Rock crystal.—Rock crystals were formerly obtained from some small pits sunk in the quartzites at Aurangpur, about 15 miles south of Delhi. The pits are now abandoned and fallen together, but the small crystals of quartz spread about round the pit are very numerous. Probably the rock crystal was obtained from some quartz vein running through the quartzites.

Marble.—Marble is of frequent occurrence among the Arvali rocks, and is extensively quarried in several places. It is generally white, but coloured marbles are occasionally met with, as at Kho and Baldeogarh, and black marble is found in the Motidongri ridge in Ulwar.

The most extensive quarries are those of Makrána, situate on the western edge of the Arvali range in Jodhpore. The marble forms a long ridge running nearly north and south. It is nearly vertical and regularly bedded; and some of the beds being upwards of 2 feet in thickness, large blocks can be obtained. The quarries are confined to about 20 feet of the section, but extend in length for several hundred yards.

Marble is also extensively quarried at Jheri, in Ulwar, and Raialo, in Jeypore.

A coarse kind of marble is quarried at Sarangwa, about 6 miles west of Desuri, on the western side of the Arvali range, in Oodeypore.

Steatite.—The steatite or soap-stone of which the models of the Taj and other ornamental carvings are made at Delhi and Agra is, I believe, quarried in the ridge at Mora Bhandári, about 12 miles north-west of Hindaun, in Jeypore.

FURTHER NOTES ON THE CORRELATION OF THE GONDWÁNA FLORA WITH THAT OF THE AUSTRALIAN COAL-BEARING SYSTEM, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

In my Talchir-Karharbari flora[1] I had an opportunity to point to the greater resemblance of this flora to that in the Bacchus-marsh beds in Victoria, than to that of the New-castle beds, from the great abundance of the genus *Gangamopteris* in both, and I quoted a passage from a letter of Mr. C. S. Wilkinson, Government Geologist, to the late Rev. W. B. Clarke, which the latter had sent me for perusal, and from which it was apparent that Mr. Wilkinson assigned to our coal flora a higher position than that of the New-castle beds and lower coal-measure flora. In my notes to Mr. Clarke, which he published in his "Remarks on the sedimentary formations of New South Wales,"[2] I assigned

[1] Pal. Ind., XII— 1, p. 81, 1879.
[2] Sydney, 1878, 4th edition, pp. 163—164.

to the Bacchus-marsh sandstones a position which would bring them on about the horizon of the Hawkesbury beds in New South Wales. This seemed natural, as the Bacchus-marsh sandstones are considered as Lower Mesozoic,[1] and the Hawkesbury beds overlying the upper coal-measures or New-castle beds were treated of by the late Rev. W. B. Clarke under the heading "Mesozoic or secondary formations."[2]

I have since received several communications from Mr. C. S. Wilkinson on his observations of certain physical phenomena in the Hawkesbury beds, which would tend further to correlate these beds with the Bacchus-marsh sandstones, in which similar phenomena were observed. As Mr. Wilkinson has lately published these observations in a paper in the Journal of the Royal Society of New South Wales (December 1879), and has favoured me with a copy of the same accompanied by a letter, in which again reference is made to the Hawkesbury beds, I may, besides from this paper, quote also from his previous letters.

In a letter dated 30th September 1878, Mr. Wilkinson wrote thus:—"I have noticed certain deposits in the Hawkesbury series, apparently due to *ice action*, which would seem to confirm your view as to the correlation of that series and the Bacchus-marsh beds (in which Daintree has described the occurrence of glacial deposits) with your Talchirs. Yet it is strange that in the Hawkesbury beds we have not found the *Gangamopteris*, which is so abundant in the Bacchus-marsh and Talchir series."

The absence of *Gangamopteris* would in this case be no objection against a correlation of the Bacchus-marsh beds and Hawkesbury beds, because the correlation of the Indian Talchirs with the Ekka beds in South Africa and with the Permian Breccia in England is also based upon these similar physical phenomena only.

In a subsequent letter dated 25th October 1879, Mr. Wilkinson wrote again thus:—"Recently in company with Dr. von Haast, F.R.S., of New Zealand, I again examined the Hawkesbury beds, and the Doctor quite coincides with the views which I mentioned to you in a former letter, that these beds contain many ice-borne boulders."

In his recent letter dated 20th July of this year, he again writes with reference to the Hawkesbury beds:—"Your correlation of the Hawkesbury beds with the Bacchus-marsh beds is, I think, correct, yet it is very strange that in the former we do not find the *Gangamopteris*. This, however, may be due to the fact that in Victoria the *Gangamopteris* has only been found near the ancient margin or shore-line of the formation where the latter junctions with the Silurian, whereas our Hawkesbury fossils were obtained from beds many miles from the margin of the formation, so that the *Gangamopteris* may yet be found when searched for near the margin."

[1] McCoy: Prodr. Pal. Victoria, Decade II (*Gangamopteris*). Brough Smyth: Report of Progress, etc., 1874, p. 34.

[2] Mines and Mineral Statistics, etc., 1875, p. 181 *et seq.*

From his published note (*l. c.*) the following passages may be quoted (pages 2 and 3[1]).—"Had the boulders of soft shale been deposited in their present position by running-water alone, their form would have been rounded instead of angular. It would appear that the shale beds must have been partly disturbed by some such agency as that of moving ice, the displaced fragments of shale becoming commingled with the sand, and rolled pebbles carried along by the currents.

"From their lithological character, the Hawkesbury rocks appear to have been formed in a comparatively shallow sea which was subject to rapid and changing currents. ...... it is on the rocks near the ancient shore line that we should more especially expect to find ice-grooved pebbles, but none have yet been discovered.

"I may here remark that the sandstones and conglomerates (*Gangamopteris beds*) of Bacchus-marsh, in Victoria, have been correlated by Dr. Feistmantel with the Hawkesbury series of New South Wales. Some years ago I assisted the late Mr. Richard Daintree in making a geological survey of the district in which these conglomerates occur, and both Mr. Daintree and Mr. A. R. C. Selwyn, F.R.S., then Government Geologists, in their published reports have expressed their belief that glacial transport had been concerned in the deposition of these rocks."

From all these notes it appears evident that there are in the Bacchus-marsh beds and the Hawkesbury rocks certain physical phenomena by which these two formations may be correlated: and in the 4th edition of his Remarks on the sedimentary formations, &c.,[2] Mr. Clarke again treats of the Hawkesbury beds under the heading of "Mesozoic or secondary formation;" and in another place (*l. c.*, p. 155, Appendix XVIII) as supracarboniferous. As regards their geological position, it may be mentioned that they overlie the "upper coal-measures" or "New-castle beds" which represent the close of the palæozoic rocks in Australia.

This correlation of the Bacchus-marsh beds and Hawkesbury rocks is of no small importance with regard to our Indian coal flora; for, as mentioned before, the Talchir-Karharbári beds show the closest relation to the Bacchus-marsh beds, not only from a palæontological point of view (predominance of *Gangamopteris*), but further also from the phenomenon of "ice-borne" boulders in the Talchir and the Bacchus-marsh beds; and consequently the Hawkesbury beds would have to be placed also on the same horizon. This would have the necessary consequence that the flora of the Damuda series and that of the Australian coal-beds would differ in range, the former being *above* the Talchirs, the latter *below* the Hawkesbury beds. The case might be illustrated thus (also including the South African formations) :—

[1] This refers to the pages of the abstract, the volume of the Journal of the Royal Society, N. S. W. (Vol. XIII, 1879) in which this note is published not being yet at hand.

[2] Sydney, 1878, p. 70.

			Australia.	
South Africa.		India.	Victoria.	New South Wales.
Jurassic beds.	Gondwana system in India, a continuous series of beds.	Upper Gondwánas (*Glossopteris*, very rare).	Upper mesozoic (Bellarine beds).	Mesozoic (Clarence river).
Karoo beds (*Glossopteris*, frequent).		Panchets and Damudas (*Glossopteris* abundant in the latter).		Wianamatta beds and
		Karharbári and Talchir (*Glossopteris*, less; *Gangamopteris*, predominant).	Bacchus-marsh-beds. (*Gangamopteris*, abundant;	Hawkesbury rocks;
Ekka bed (Boulder bed, ice-action).		(Talchir boulder bed, ? ice-action).	Boulder bed, ice-action).	(Boulder bed, ice-action).
Unconformity, break.		Unconformity break.	Unconformity break.	Upper coal measures. (New-castle beds; *Glossopteris*, abundant). Upper marine beds. Lower coal-measures. (*Glossopteris*, first appearance). Lower marine beds.
				Devonian.
			Silurian.	

This list does not need any further comment. It would appear that the unconformity and break, which exists in Africa, India, and Victoria, between the Ekka beds, Talchir beds, and Bacchus-marsh beds respectively, and their underlying rocks, is in New South Wales filled in between the Hawkesbury rocks and the Devonian beds by the series of the Australian coal-bearing beds. If this surmise be correct, then an older age, than carboniferous, for the Vindhyans of India, would be an almost necessary consequence.

NOTE ON REH OR ALKALI SOILS AND SALINE WELL WATERS, *by* W. CENTER, M.B., *Chemical Examiner, Punjab Government.*

A reference was made to this office by Government regarding the treatment of reh or saline soils by chemical manures. My predecessor, Dr. Brown, had written a report regarding the use of nitrate of lime as a remedy, and a copy of this was asked for. It could not be found in the records of the office, but I afterwards found that it had been published in the Selections from the Records of the Office of the Financial Commissioner, and the gist of it was embodied in Powell's book on Punjab Products. As I had made numerous analyses of such efflorescences, and studied their connection with saline well waters, samples of which I had analysed from all parts of the Punjab, and as I had an opportunity of observing and learning something of similar soils known as alkali soils in the Utah

Basin and other parts of America, and of the methods used to reclaim them, I beg to submit a few notes on my observations. I am indebted to Captain Ottley, of the Irrigation Department, and Mr. Miller, Secretary to the Financial Commissioner, for access to the literature on the subject in the form of reports to Government. I propose considering more especially the chemistry of the production of those salts and the conditions of their accumulation in soils and in the underground water,—points intimately connected with each other, and equally important in the agricultural and sanitary aspects. The efflorescences consist chiefly of sodium chloride and sulphate in varying proportions. In addition there is sometimes carbonate of soda, and I have usually found some magnesian sulphate. In certain localities the last-named salt is in very considerable proportion. In other cases nitrate of lime or alkali is present.

Marine theory.

2. Various theories have been started regarding the origin of these efflorescences, the oldest being probably the marine theory. According to this the Indo-Gangetic depression was considered to be an old sea bed, the soil of which became impregnated with salts from the existence of shallow "rans" and lagoons in a former geological age. In favour of this it might be mentioned that there is certain geological evidence that an Eocene sea covered the Punjab plain, its shore coinciding with some part of the outer slope of the Himalaya, with a gulf or gulfs penetrating the mountains as far as the valley of the Upper Indus. On the other hand, to the east of Kumaun and to the north of the Gangetic valley, the situation of this shore line is obscured till the Assam region is reached. The theory of recent marine impregnation is now entirely to be abandoned. It is proved beyond doubt that the whole of the materials of the Indo-Gangetic basin are fresh water alluvia to an unknown depth, and consist in fact of the debris of the Himalayas carried down by its drainage and deposited in this immense depression. There are no deep natural sections in which to observe the structure, but in the Umballa boring of 701 feet, the Calcutta boring of 481 feet, and that near Rajanpur of 464 feet, nothing but fresh-water alluvia were met. We do not speak here of the Salt Range region, in which are accumulations of salt as old as the Silurian period.

True origin of reh.

3. The true origin of reh or alkali efflorescence is the decomposition of the elements of rocks and soils which is continually going on under the action of air and water. The accumulation of the resulting salts in superficial soils or in subsoil waters depends on various conditions of chemical constitutions and permeability of soils, and on the nature of the surface and subsoil drainage, which will be considered in detail.

Decomposition in hill regions.

4. If the rain water that runs off the surface of the hills be examined, it is found to have washed out appreciable amounts of soluble salts, chiefly carbonate of lime and alkaline chloride and sulphate. If such water runs off crystalline or schistose rocks, the amount of salts washed out may be extremely small,—even 2 grains per gallon, as at Dalhousie. If it runs off a loose decomposing rock the quantity may be considerable,—for example, 8 grains near Murree. The rainfall that percolates the debris of the decomposed rock which covers the surface of the hill-sides and fills up the channels of ravines issues in springs at lower levels. and is [illegible] to contr[illegible]

much greater proportions of the same salts. This water not only comes in contact with a larger quantity of degraded rock and washes out its soluble salts, but it takes up more carbonic acid from the air in the pores of the ground, which is rich in this gas, and this dissolves more lime and magnesian carbonate. From 10 to 25 grains per gallon are found in springs in clean soils in various hill stations. In the hill stations themselves, where the porous subsoil becomes loaded with sewage impurity from human habitation, the dissolved salts and organic impurity may be very great. For example, in the bazar well at Murree I found 35 grains per gallon in which were 12 grains of common salt. This last is, however, a sanitary fact, and I wish at present to speak generally of the saline ingredients washed out of such soils not contaminated by human occupation.

5. The soluble substances produced by rock decomposition and dissolved by water are remarkably uniform in their nature, though varying in amounts, both relative and total, according to the nature of the decomposing rock or soil. It may be generally stated that the earth water shows a fugitive acidity from the presence of free carbonic acid and a slight permanent alkalinity from the presence of alkaline carbonate, but that the main ingredients are carbonates of alkaline earths, chiefly of lime, and alkaline chlorides and sulphates, chiefly of soda. Other ingredients are generally in smaller amount, such as lime and magnesian chlorides or sulphates forming the permanent hardness, also silica, traces of iron, &c. Of course in special formations it may be highly charged with peculiar salts, and may even form what are called mineral springs; but we are speaking generally of the body of water that filters from the hill-sides, and either sinks into the underground strata of the plains or finds its way into the streams and rivers, and thence into the sea, the great natural reservoir of the soluble salts washed out of the earth. The waters of the Punjab rivers which I have examined, the Ravi, Jhelum, and Indus, contain 8 to 15 grains per gallon, varying according to the floods. The amount of soluble salt capable of efflorescence varies from about 2 to 4½ grains. The river waters are most concentrated when they are at the lowest. At that time they are supplied by the water that has filtered through the soil and subsoil of the higher regions, and has thus taken up more salts. In the hot weather, when the glacial water comes down, and in the rain floods at the end of the hot season, the dilution is at its highest. Other glacial rivers and those subject to annual floods show the same thing. For example, the total solids in Nile water vary from 9½ to 14½ grains per gallon.

Ultimate origin of reh salts.

6. To explain the ultimate origin of these salts we have to consider the action of the oxygen and carbonic acid in rain water on the rock elements. With the exception of the limestone strata, which consist of carbonate of lime, often with carbonate of magnesia, all great rock formations are composed of silica and silicates, chiefly of alumina, lime, magnesia, soda, and potash, with smaller amounts of iron and other metals. Such is the constitution of the granites, gneisses, slates, traps, &c. The old sedimentary rocks are similar in composition, being formed by the disintegration of these. The recent alluvia of the plains consist of finely-divided debris of the limestone and silicious groups, and in them the chemical decomposition going on under the influence of air and water is much intensified, owing to the state of fine division

which favours chemical action, and because the constituents of the soil are further advanced in the path of degradation.

Origin of carbonate of lime alkaline carbonate.

7. In order to understand the slow chemistry going on in the ground, we have to conceive the outer shell of the earth generally covered with more or less vegetable mould, and permeated to its greatest known depth by meteoric water. There is no rock, however compact, and there is no depth to which man has penetrated, in which water is not found to have permeated by pores, cracks, or fissures. The great agent of change is the carbonic acid of the air. This is dissolved in rain water, which also dissolves more from the decaying vegetable mould and from the air in the pores of the ground, which is rich in this gas. It has two great functions. It attacks the silicates of the alkalis and lime, forming carbonates. It further dissolves the carbonate of lime, enabling it to be transported by water and to be redeposited on evaporation. From the limestone rocks the water takes up carbonate of lime and magnesia, which dissolve in its free carbonic acid, and in such formations it becomes very hard. The amount of carbonate of magnesia dissolved is always much less than that of lime. In the silicious rocks the felspathic family of minerals decomposes most readily. These consist of silicates of alumina and alkali, with generally small quantities of lime and magnesia. The white or soda felspar, which contains more soda than potash, is a common ingredient of the Himalayan rocks, and the decomposition of this in soils may possibly to some extent account for the very great excess of soda over potash salts. The chief reason, however, depends on the fact which has been experimentally verified, that in a silicate containing both potash and soda the latter is dissolved out with greater facility and in much larger quantity than the former. The process of decomposition consists in removal of the alkali by the action of carbonic acid, while water is taken up, leaving hydrous silicate of alumina or clay. The presence of alkaline water also assists in promoting the breaking up by dissolving some silica. Another group, the lime silicates, is also readily decomposed by the action of carbonic acid or alkaline carbonate, and forms an additional source of carbonate of lime. On the other hand, the talcose rocks, which contain magnesian silicate, are hardly attacked at all. This magnesian metamorphosis of rock, which is very extensive and very ancient, is also the most permanent, and apparently a final one. We have thus accounted for the alkaline carbonate and carbonate of lime. The earth water is almost always slightly alkaline, and this plays a most important part in the decomposition of the silicious rocks and their metamorphosis. The alkaline carbonate rarely, however, appears in large amount, because it partly expends itself in decomposing silicate of lime, thus forming carbonate of lime, and if free carbonic acid is present, this will be dissolved and carried away by the water. If magnesian or lime sulphate be present, the carbonate of soda with these will produce lime or magnesian carbonate; while sulphate of soda will be found in the solution. It thus happens that the waters of the rivers contain apparently no alkaline carbonate, but show a permanent neutral re-action. All the river waters, in addition to carbonate of lime, which is their chief ingredient, contain also lime and magnesian sulphates which there has not been enough alkaline carbonate to decompose.

8. The circulation of the sulphur that occurs in the earth is very interesting. That which forms the sulphates in the earth-water appears to be derived from the sulphurets, especially of iron, which are so universally diffused in rocks, and from the gypsum rocks, which, however, form an insignificant portion of the strata. The sulphate of lime being moderately soluble may be readily taken up by water. The sulphurets become oxidised by the oxygen in air or water, leaving red iron oxide, which gives the yellow or red colour to soils and clays; while the sulphuric acid attacks the silicates and unites with soda or lime. In the strata of the earth are found deposits of sulphates of lime, but these appear to have been deposited from solution by infiltration, or by evaporation, as in the Salt Range. Their ultimate origin is probably the same as that just indicated. The presence of sulphate of lime in soils leads to the production of sulphate of soda. The former salt is slightly soluble, and as the earth-water contains alkaline carbonate, mutual decomposition leads to the formation of carbonate of lime and sulphate of soda. This partly accounts for the excessive proportions of sulphate of soda often found in reh. The sulphates may be again reduced to sulphides by organic matter from the vegetable mould or other sources, which accounts for the presence of sulphuretted hydrogen in dirty well waters rich in sulphates.

Origin of sulphates.

9. As regards the chlorine of the alkaline chlorides, there is more difficulty. Chlorine is not an important chemical constituent of any common minerals forming rocks, but there is no rock that on being powdered and washed with distilled water does not show its presence. The only explanation known of its appearance lies in the fact that, though generally in minute quantities, it is the most universally diffused substance we know. Even in air a chemically clean platinum wire cannot be exposed for some time without showing the sodium line in the spectroscope due to sodium chloride which can be extracted from the air dust.

Origin of chlorides.

10. There is next to be considered the chemistry going on in the decomposition of the debris of the rocks forming the plain. It is in a more finely-divided state, and is therefore in a condition more favourable for chemical action, and besides the constituents are in a further advanced state of decomposition than in the fresh rocks. The action that has been described is therefore intensified. It has been proved by experiment that it is from the most finely-divided clay (felspathic) particles of soils that most of the soluble substances can be extracted. These particles are so extremely fine that under the microscope they are seen only as minute dots. The other small particles which are of measurable dimensions are silicious, and yield to acids only a slight amount of soluble matter.

Formation of salts in the plains.

11. There are three points to be considered,—the action that takes place on the surface, that which takes place in the strata permeated by the underground water, and also the relations between the two.

12. On the surface undoubtedly the greatest amount of decomposition goes on from the united action of air, moisture, heat, and light. This produces the perennial supply of soluble salt necessary for the growth of plants, and in cultivation it is assisted by turning up and

Surface production of salts.

pulverising the soil and acting on it by water. In countries with good surface and underground drainage there is a constant escape of these salts, and the difficulty may be how to get enough of them. In many parts of our plains circumstances favour their accumulation, and the question is how to get rid of the excess. I have frequently taken samples of soil and subsoil from places where there were efflorescences and where there were none, and on washing out the soluble substances with boiled distilled water found that they were similar, but different in amounts. They always consisted chiefly of alkaline chloride and sulphate, with often small quantities of alkaline carbonate, and frequently larger amounts of soluble magnesian salt, sulphate or chloride. Another experiment was to take a sample of reh soil and wash it repeatedly till no trace of soluble salts could be found. It was then dried and thoroughly mixed and a portion tested again to see that no soluble salt was present. It was then placed on a filter and covered with porous filter paper so as to exclude dust, but allow evaporation, and the bottom of the glass filter was corked. It was frequently watered with distilled water charged with carbonic acid and exposed to the heat and light of the sun in the hot weather for nearly three months. At the end of that time it showed no efflorescence, but on being washed with distilled water the solution showed the presence of considerable quantities of alkaline chlorides and sulphates. This experiment proved that in that species of soil a sensible production of reh salt may take place in a few months. A similar sample irrigated with ordinary well water rapidly developed an efflorescence owing to the presence of salts in the water. There is nothing particularly novel in these results. Experiments have often been made of grinding down the solid rock from the debris of which the adjoining country was formed. On washing out the powdered rock the solutions were found to contain the salts of the water of the district; indeed it is always possible to account for the composition and proportions of the ingredients in a water draining any area if the structure and composition of the rocks are known.

Approximate estimate of decomposition in soils: the Lysimeter.

13. To estimate approximately the decomposability of a soil, the simplest method is to dry and weigh a sample and wash out from it the soluble salt already present. On drying and weighing the residue and deducting its weight from the original there will be found the soluble salt (along with some organic matter). This is the result of decomposition already accomplished. The solution may be tested in the usual way, by evaporation to find the total dissolved matter, and by ignition to find organic matter. The washed residue of earth is then ignited to expel all remaining organic matter, and treated with hydrochloric acid, which will decompose and dissolve the materials which are in an easily decomposable state. The solution will contain lime, magnesia, alumina, and iron, and also the alkaline bases capable of efflorescing. On deducting the undissolved residue from the former, a figure will be found, which will be an approximate index of the facility of decomposition of the soil. The hydrochloric acid solution can be examined in the usual way if required by first precipitating the iron, alumina, and phosphates of the alkaline earths, then the lime, and afterwards separating the magnesian and alkaline bases. The last will show the salt capable of efflorescing. A more

correct way is to perform an experiment similar to what I have described before with the glass funnel. A zinc box is made open at the top and closed at the bottom, with a false bottom of perforated zinc half way down. The section is usually 1 square foot. Earth is placed above the perforated zinc, and the whole is exposed to the varying conditions of the season and climate, as rainfall, heat, moisture, &c. All water that falls sinks through the perforated bottom, and is collected or evaporates. After some months or a season the solution in the bottom of the box and the earth are examined in the usual way to find the results of decomposition. Such an instrument is called a Lysimeter, and has the advantage of demonstrating the changes that take place, not by the action of acids, but by the ordinary operations of nature.

Underground production of salts.

14. Another source of generation and accumulation of these salts takes place in the strata moistened by the underground water. This is partly derived from percolation of rainfall from the surface where it is sufficiently porous. In its passage downwards it washes out any soluble salts it meets and carries them down till it reaches the impermeable stratum. In the second place the air contained in the vegetable mould and porous ground is rich in carbonic acid, and this is absorbed by the water and enables it to dissolve more lime and magnesian carbonate, which accounts for the much greater hardness of subsoil waters. In the third place the alkaline water charged with carbonic acid not only promotes the decomposition of the strata through which it filters, but by a constant soakage action on that which it moistens produces still more. The amount produced would be in a great measure proportional to the time the water remains in contact with the stratum. In stagnant underground waters in the middle of the plains, as at Chunga Manga and Wanradaram, the dissolved salts amount to 400 grains per gallon. Another feeder of the underground water is the percolation of hill water that sinks into the porous fringe at the base of the hills. This, however, affects particularly the plain near the base of the hills. The solution formed from the debris on the hillside is much less saline than that from the finely-divided and more degraded materials of the plain. The hill percolation therefore affects the underground water near the hills in two ways. It raises its level by hydrostatic pressure and it makes it less saline by dilution. There is still another source of underground waters in the percolation from rivers, streams, and canals. The neighbourhood of rivers affects the water-level, and very sensibly influences the quality of the subsoil water. Analyses of waters taken from wells near them show that they closely approximate to the river waters, being little more than those filtered. For example, the well water near the Ravi was found to contain from 8 to 15 grains per gallon, that near the Jumna 9·8 to 14 grains. Advantage is now being taken of this in supplying water from such wells to some large cities in the Punjab. The influence on the quality of the subsoil water, however, only exists in the khadar land, or low river valley. In the bhangar, or bar land, the upland that lies between neighbouring rivers, even at short distances from the valley, the water may be highly saline. In the case of canals, as far as my observation goes, there is very little percolation in the districts I have seen irrigated by the Bari Doab Canal, on account both of the impermeability of the soil and

the disposition of the strata. If, however, a canal were made on a natural line of drainage, as I have heard the Western Jumna Canal is, it might influence the adjoining ground in the way I have mentioned in the case of rivers, both as to the water-level and quality of percolating water.

Nature of reh and its varieties.

15. When rain water sinks into a soil containing soluble salts, it dissolves them and carries them down till it reaches an impermeable stratum. Medlicott has pointed out the action of the first rain drops in carrying efflorescent salts down, so as to be in a great measure out of the reach of the surface scour of the succeeding rainfall. If the soil is porous, it may gravitate down to the water stratum, which then becomes a reservoir of the surface salts. If it is only slightly porous, as in alluvial soils containing much clay, the soakage is only superficial to one or more feet in depth, and generally in such cases the surface soil is more or less porous from atmospheric exposure, and below it lies a more compact clay subsoil. As rain water contains free carbonic acid, it dissolves also carbonate of lime and magnesia if these be present in the soil. When evaporation succeeds, it draws up the moisture in the more porous surface soil by capillary action. As the water and carbonic acid pass off, the solution becomes more concentrated and carbonate of lime is re-deposited. This last action takes place first, and as the concentrated solution is drawn up to the surface, it finally deposits its most soluble salts on drying as an efflorescence on the surface. An essential condition is the dryness of the climate. In more temperate, but dry regions, as in the Utah Basin and the elevated parks or plateaus of the rocky mountains, efflorescences appear as well as in the scorching plains of India. The action, however, is intensified by heat, which increases evaporation. By similar capillary action the moisture will creep up the sides of objects lying on the ground, such as pieces of brick, and deposit a copious efflorescence. At first it appears in glittering crystals, but as the sodium sulphate gradually loses its water of crystallization, it breaks up into a copious white powder of anhydrous salt, and it is then that it is most apparent. The carbonate of soda behaves similarly, but the sodium chloride does not, having no water of crystallization. Nitrate of soda and lime deliquesce in damp air. During the hot months, the salts, if brought up by rain, melt in their water of crystallisation. By the word efflorescence we do not mean here what is known as such in chemical language, that is, the breaking up of a crystallized salt into a powder from loss of water of crystallisation. What is meant is efflorescence in the physical sense, or the appearance on the surface of the ground of soluble salts brought up by capillary evaporation. It is true that sulphate and carbonate of soda effloresce in the chemical sense, but chlorides and nitrates do not.

16. From what has been explained regarding the origin of the salts dissolved out of the earth, it can be understood how the solutions can naturally be divided into two groups, whether they be river and canal waters, or well waters, or solutions formed when rain water soaks a saline soil. There are first the neutral solutions from which carbonate of soda has almost or entirely disappeared, having been used up in decomposing any soluble lime or magnesian sulphate or chloride and precipitating their carbonates. To this belong the river and canal waters, the chief ingredient of which is carbonate of lime with less amounts of

magnesian carbonate held in solution by free carbonic acid. There is present probably next in amount soluble salt of lime and magnesia, sulphate or chloride—the magnesia in smaller amount. The alkaline chloride, though the most constant ingredient in all waters, is in small amount, from ½ grain to 2 grains, and the alkaline sulphate in about equal or larger quantity. In the majority of well waters in the plains in my experience there is high permanent hardness, indicating lime or magnesian sulphate or chloride, and sodium carbonate is deficient. The total dissolved salts is in fresh well waters about double that in rivers and canals, and may rise in saline wells from 10 to 40 times the amounts, the increase being chiefly in carbonate of lime and alkaline chlorides and sulphates.[1] The second group of waters or solutions is that containing carbonate of soda. In these there is generally little permanent hardness, or soluble lime or magnesian salt. If these two groups on evaporating produce efflorescence, in the first we may have sodium chloride and sulphate, and any magnesian sulphate, if present; in the second we may have sodium carbonate with sodium sulphate and chloride, but no lime or magnesian salt. During the process of drying, which leads to the efflorescence, the first thing that occurs is the deposition of lime and magnesian carbonate, as the free carbonic acid disappears. Subsequently, sulphate of lime being only little soluble would deposit, and the highly soluble salts, including sodium carbonate, chloride and sulphate, magnesium and calcium chloride and nitrate and magnesium sulphate, would be capable of efflorescence. These salts, however, are not deposited as they exist in solution, as new laws come into play. The chief of these is, that during evaporation the least soluble salt that can be formed is first deposited; but this is modified by two other laws, the tendency of certain compounds to form double salts, and the tendency of substances with the same crystalline form to crystallize out together. The efflorescences thus produced consist of three groups; 1*st*, the neutral, containing no carbonate of soda, consist chiefly of sodium chloride and sulphate, and frequently magnesium sulphate; 2*nd*, the alkaline, containing carbonate of soda and alkaline chlorides and sulphates, but no lime or magnesian salt; 3*rd*, the nitrous efflorescences. These generally contain no alkaline carbonate, and consists chiefly of nitrate of lime and alkaline chlorides. Others contain alkaline nitrate, chloride, and sulphate. They are developed where the soil has become loaded with organic nitrogenous matter. In several places about Lahore there is a good deal of magnesian sulphate, and I have observed on twigs of farash trees a saline coating of this salt. Reh is thus not a special salt or mixture of salts, but a very variable compound. It is really the most easily soluble salt in the earth-water, remaining in solution after the deposition of carbonate of lime, &c., on evaporation. The ingredients and their relative proportions are found to vary in different places, exactly as the well waters at different spots differ in saline contents, and in the same area there is a

[1] Though we speak usually of individual salts existing in a solution, this is not, strictly speaking, scientifically correct. If, for example, sodium chloride and lime sulphate be made into a solution, it will really contain quantities also of sodium sulphate and lime chloride, and the amounts of the four salts will depend on the masses of the first two, temperature, concentration, &c. Properly speaking, in recording an analysis, the total amount of acids and bases should be separately recorded. By a conventional rule, however, it is customary to arrange the salts hypothetically.

close relation between the two. The relative proportion of common salt to sodium sulphate was found by Medlicott to vary from 4 to 24 per cent.

Formation of kankar.

17. The re-deposit of carbonate of lime gives rise to those nodules known as kankar. It takes place at the upper margin of the impermeable subsoil. They are not formed by the lime depositing round a nucleus and pushing the other elements of the soil aside. A portion of rather porous soil, consisting of a mixture of lime, sand, and clay, is infiltrated with water retained in it by an impermeable bottom. The carbonate of lime is deposited throughout this porous mass, and cements its particles together till it becomes of a stony hardness. Deposit no doubt also takes place along the outer surface, as each former minute crystal deposited acts as a nucleus for further deposit. The formation is often seen in an incomplete state, nodules of soil having become only partially hardened. The process is essentially one of segregation from the soil itself. Such nodular formations, which are very common with other minerals, as iron oxide, silica, &c., are an example of the simplest kind of metamorphosis going on in rocks and soils. It is not necessarily connected with efflorescences on the surface. The essential condition of its existence is the presence of carbonate of lime, or its ready production by ordinary decomposition in the soil. In soils and sub-soils which supply little lime there may be efflorescences without formation of kankar, as in those consisting of clay and silicious sand. On the other hand, in marly soils, in which there may be little production of alkaline salt, kankar may form without any efflorescence. The analysis of kankar very well illustrates their mode of formation. They show from 20 to 50 per cent. of carbonate of lime, the rest consisting of the mixture of clay and sand of which the soil is composed.

Estimation of reh in soils and water.

18. To estimate practically the amount of injurious reh in any soil, it should be washed with boiled distilled water and the solution evaporated, then burned to expel organic matter and finally weighed. In the case of the waters of rivers, canals, and wells, they should be evaporated, ignited, re-carbonated, and weighed. The easily soluble salts should then be washed out with a little distilled water and the residue weighed. The portion undissolved consists of lime and magnesian carbonates and some sulphate of lime with small amounts of silica, &c. The difference between the two weights is the amount of salt capable of efflorescing. If one have a record of the analysis of any water, a rough approximation is got by deducting from the total solids the volatile matter (almost all organic), also the removable hardness consisting of carbonate of lime. In addition two grains per gallon of carbonate of lime should be further deducted, as in boiling (in order to remove carbonate of lime), two grains per gallon still remain dissolved. A still further deduction would require to be made for silica, iron, &c., but these are in small amount. I mention these methods of approximate estimation because they are readily applied and are useful for all practical purposes.

Causes of accumulation of salts.

19. In considering the conditions that lead to accumulation of salts on the surface or in the underground water, it is to be borne in mind that soils exposed to moisture, air, and heat are continually generating them, and that in some in which the felspathic elements

are undergoing rapid decay the production may be profuse. Also all water, river, canal, or underground, that has washed over or filtered through the ground, contains similar salts and promotes their further production.

Accumulation in basins.

20. The simplest case of accumulation is that of a closed basin like the Utah Basin. The surface water washing the salts off the ground has no escape to the sea, and forms an inland salt lake. The soil in such cases is very saline, except in places where there is slope to allow thorough surface washing by rainfall, or permeability to allow the surface salt to be washed down to a deep ground water. In the centre of the depression both the surface and sub-soil and the sub-soil water are loaded with salt. The efflorescences in Utah closely resemble those in the Punjab, the main common ingredients being sulphate of soda, common salt, and often sulphate of magnesia. In some places there is a large amount of carbonate of soda, in others borax is present. In the Caspian Basin the main ingredients are sulphate of soda and common salt. The very opposite case is a hilly or undulating country with sufficient rainfall and good natural surface drainage, the strata of which are also inclined, thus allowing of natural sub-soil drainage till the underground water finds an outlet at the outcrops of the strata, or where they are laid open by natural sections of the country. Here the salts continually formed are either washed off the surface or are carried down to the sub-soil water which drains them off.

Accumulation in plains.

21. In examining the state of things in the Indo-Gangetic plain, it is necessary to consider the structure of the country. The Himalayan axes stretching along the north of the plain are elevated cores of granitic gneiss flanked by metamorphic and limestone rocks. To the south of this is the Siwalik fringe with its dúns, consisting of clays, sandstones, and conglomerates. These are fresh-water deposits formed by river and torrent action in the tertiary period, and having suffered displacement by the Himalayan elevation, they are seen to pass with great undulations and numerous fractures under the strata of the plain. This formation conducts water under the plain. There succeeds to this the recent gravel deposits from the outer hills, brought down by river and torrent action, similar to that which caused the Upper Siwaliks, and known as the Bhábar. This is extremely porous, and a great part of the water of the streams passing over it sinks into the ground and issues in springs at a lower level in the adjoining part of the plain, which is known as the Terai. Part also sinks beneath the plain and raises the ground-water level. The great alluvial plain itself is composed of horizontal strata. Near the hills are gravel deposits, but further off the soil and sub-soil to an unknown depth are composed of deposits of clay, sand, and mixtures of the two in various proportions, according to the stream or lake action that deposited them. Diffused through these are found mica and small quantities of carbonate of lime, which makes soils more or less marly, and iron oxide which gives them a yellow or red colour, and minuter amounts of sulphate of lime and other salts. From numerous well sections it is seen that these alternating permeable and impermeable beds of sand and clay are not continuous, but that they thin out and are replaced horizontally by others. This is observed even at

short distances. Possibly many of the sheets of clay may have more or less of a basin form. The important points for us to remark in considering the surface and sub-soil drainage are that this immense plain has an average breadth of about 200 miles, that practically the Gangetic and Punjab plains are one, the water-shed between the two being only perceptible by accurate scientific measurements, and that its length is about 1,200 miles. There are also no deep natural sections exposing outcrops of the deep strata so as to allow of escape of underground water to the sea. In consequence of the very small surface slope, and on account of the horizontal disposition of the strata over such an enormous area, the conditions as regards drainage approach to those of a basin. The surface drainage is weak, but ultimately finds its way by the rivers to the sea, but the underground drainage is usually imperceptible.

22. As regards the production of efflorescences, we have further to consider that in the Punjab there are three belts of plain. That adjoining the hills, the sub-montane tract, has a plentiful rainfall and moister air; south of this is a sub-desert tract with small rainfall, and still further south is the desert country with deficient rainfall. In the sub-montane belt the rainfall is sufficient to scour the surface, and as it is more permeable from the presence of gravel and sand, and has greater slope, the surface and subsoil drainage are more efficient. In the other two tracts the working of these agencies is defective. In the hills themselves the annual rainfall of a series of years is as follows: Murree, 56·8 inches; Dharmsala, 123·2 inches; Simla, 68·6 inches. This does not include snowfall however. In the sub-montane belt we would have—Rawalpindi, 32 inches; Sialkot, 39·3 inches; Gurdaspur, 33·1 inch; Hoshiarpur, 36·5. Of the less-watered region there is Lahore, with 19·3 inches; Shahpur, 14·5 inches; Sirsa, 14·5 inches; while about Mooltan the rainfall is 6·9 and at Dera Ismail Khan 8·2.

23. The simplest case to consider is that which occurs in the more desert country, in which the rainfall is only enough to moisten the surface and promote decomposition. If the soil is sandy the dissolved salt is carried down to the underground water and the accumulation takes place there. If the ground is not porous, as where clay predominates, only the upper portion is soaked, and on drying the soluble salts are brought to the surface. Instances of both these cases are found everywhere along the southern portion of the Punjab plain. In the middle portion of the plain, where the rainfall may go up to 20 inches, similar actions take place. The first drops of rainfall dissolve any efflorescence and sink into the ground, carrying it out of the reach of surface scour, which on account of the flatness of the plains and small rainfall is slight. In the more porous portions the salt is carried down to the underground water; in the more impermeable it is brought to the surface by evaporation. It thus happens that in certain places there is a scum of efflorescence on the surface, while generally the ground water is saline. These remarks apply to the Doab or Bhangar land, the more elevated part of the plain lying betwen adjacent rivers. In this the water lies at a considerable depth, from 30 to 100 or more feet, and is more or less saline; in many places on digging deeper to another stratum fresher water is found. In the other great plains of the earth where the climate is dry

and like conditions of soil prevail, similar efflorescences are developed. In the dry pampas of South America they consist chiefly of sodium sulphate with some common salt; in the Siberian steppes, of sulphate of magnesia along with sulphate of soda and common salt. They are likewise found in the Russian steppes and the Tibetan plateaus.

24. The Khadar, or low-lying river valley, cut out by recent erosion from the old alluvial plain, usually shows little or no saline accumulation on the surface and none in the underground water. Here the circumstances are all different. In fact the river occupies the line of natural drainage of the country, and its deposits are parallel to the line of slope. Accordingly, the water percolating from the river forms a subterranean stream, gravitating down the river-course and accompanying the main stream. Its extent depends on the permeability and arrangement of the strata and the resistance of the porous beds along which it moves. In the beds of dry nullahs this gravitating water may be met on digging in the dry channels. If the underground water were stagnant, remaining long in soakage contact with the water-bed, it would become more or less saline, whereas it is found to resemble the river water filtered, though of course it has taken up some ingredients from the earth, chiefly more carbonate of lime. In two cases in which I examined the water in beds of dry nullahs, I found it much less saline than that of the surrounding plain. In the Khadar land the water lies near the surface, and may be within the reach of capillary evaporation, which would produce efflorescences, as it often does to some extent. But in consequence of the occasional washing by floods, and of the underground circulation I have described, there is no permanent accumulation either on the surface or in the ground-water.

Accumulation by evaporation from a shallow water table.

25. One of the most interesting and important cases is that in which the ground water lies close to the surface within the reach of capillary evaporation, thus furnishing an unlimited supply of efflorescence. The enquiry made by the Aligarh Committee chiefly referred to this instance. It was considered that the ground-water level had been raised by percolation from the canal, assisted by hydrostatic pressure, in consequence of the canal being above the level of the country. Other causes assigned for the rise were the obstruction to surface drainage by canal and railway embankments acting as bunds, and the practice of profuse irrigation in flooding. All these would lead to an increased body of water sinking into the ground, carrying earth salts in solution to be again brought up by capillary evaporation from the shallow water table. It is very important to be able to estimate how much is due to each of these agencies, as on the decision of this point would depend the remedial measures to be applied, such as the lowering the level of the canals, their realignment on the high Bhangar land instead of on the lower ground, the restriction of profuse irrigation, the relieving of the surface drainage, and the establishment of artificial sub-soil drainage. I am unable to enter into the merits of these most interesting points because I have never had an opportunity of making observations on an area where this mode of generation of reh was going on to a serious extent. The only portions of country I have seen in which the ground-water lies very near

the surface are the plains adjoining the hills and the Khadar* lands or river valleys. In the former the rainfall is more plentiful, the slope of the surface and deep strata are better, there is more moisture in the air, and therefore less evaporation. All these tend to prevent accumulation of salt below and efflorescence above. In the latter the washing of the surface by the floods and better subterranean drainage may account for the want of accumulation. In the parts of the Bari Doab Canal which I have seen, the ground-water lies at a depth that is totally out of the range of capillary action, and the strata consisting of alternating clays and sands are so impenetrable that percolation can have little effect on the water level. Captain Ottley informs me that on the Bari Doab and Upper Sutlej Inundation Canals the curves of the rise and fall of the well waters markedly follow those of the rainfall and do not appear to be affected by irrigation. I did not find any marked difference in the water levels of the wells near and at a distance from the canal about Lahore. A still better proof was that the salinity of the wells was not altered by proximity to the canal. If percolation to any extent existed, the wells close to the canal ought to be fresher than those at a distance. In the part of Lahore occupied by the railway station and barracks the ground-water is salt. At the end of the hot weather I found that a well a few yards from the canal contained as much salt as others far off. After the rains the same well waters were found to be so diluted as to contain less than one-half of the former amounts. The depth from which capillary evaporation can take place is also a question that ought to be investigated by observation and experiment. Much of course depends on the porosity of the soil, but in the most favourable cases one would fancy, from the known laws of capillary force, that the action would only be through a few feet, unless assisted by hydrostatic pressure. At the village of Baoli, on the Western Jumna Canal, where the reh action is very pronounced, the depth from the surface of the ground to the water table (as shown by measurements of an unused well) is 8 feet. It is said that before the Western Jumna Canal was re-opened in 1819, the water in wells about the part lay at a depth of 60 to 70 cubits, and this tradition appears to be confirmed by inspection of the records of other wells which had been sunk to as much as 116 feet, and in which now there are 62 feet of water. On the banks of water-courses and canals about Lahore in salt soils one often observes two lines of efflorescence, one a few feet above the water level at the upper limit of capillary soakage, and another some distance from the surface, at the base of the surface percolation. As regards the rise in the well water levels said to be caused by canals, it would be necessary to have accurate information as to what those levels were before the canals were made. Probably no accurate record was made before the earlier canals were started, as attention was not directed to the point.

Other modes of accumulation.

26. There are last to be noticed some other modes of distribution and accumulation of alkali salts. Irrigation by flooding and allowing the water to dry on the soil, unless it is very permeable, of necessity leads to production of salt. Not only does the irrigating water contain salt which it deposits as an efflorescence, but it also promotes further decomposition in the soil. The amount of reh in ordinary canal water

might be from 2 to 6 grains per gallon. If well water is used, the accumulation is much greater, because it contains much more salt. In places where the water is sweet, the reh may be about 6 to 15 grains per gallon; where it is salt, it may amount to more than 200 grains per gallon, as at various places on the Railway Line between Lahore and Mooltan. An extraordinary instance is mentioned in the Aligarh Report of a reh soil tried by the most energetic measures without effect. An analysis of this soil would probably have proved that the elements of the soil itself were in such a state of decomposition that most of the measures employed assisted the process. Again, water running off a saline field must necessarily dissolve a portion of its salt, and if it be allowed to run into another and dry, that salt will be deposited. The agency of wind appears to be a slight and very variable one. There is no doubt that wind blowing over a saline country and raising dust transports saline particles. Travellers over the alkali plateaus of the Rocky Mountains are familiar with the irritation caused to the eyes by this mode of transport. All these, however, are of secondary importance. The main points to bear in mind are, that there are several factors causing production and accumulation, and others leading to the removal of earth salts. Of the former there is first the soil itself. This is always generating them, and in certain cases its materials so readily undergo decomposition that perhaps even artificial means may fail to cure the evil. The next chief factor is the water used in irrigation. This always contains reh salts,—the river and canal water in small amount, but the well water often in enormous quantities. In addition, the irrigation water may not only deposit its salt in the soil, but it causes further production in the soil itself. Another cause is the special condition in which the subsoil water lies within the reach of capillary action from the surface, which may give rise to an inexhaustible supply. The factors concerned in the removal are, first, permeability of the soil, which may allow the salts to be washed down to the underground water. If this have a ready outlet, they are removed; if not, there will be a saline ground water; but the surface may show no accumulation if the water table is deep. If, however, the ground-water is a very short distance from the surface, there may be a profuse efflorescence under the usual conditions of dryness of the atmosphere and heat. The second cause of removal is copious rainfall. If the rainfall is copious, it may wash away part of the salts, and this is one of the reasons that in rainy regions alkali is rare. If it is slight and only moistens the soil without scouring it, there will be a continuous production and accumulation on the surface, except when the soil is porous and allows it to be carried down to the ground-water. The third means of removal is by vegetation, which annually takes up its necessary portion of salts and assimilates them. It is frequently observed that in cultivated spots the reh is kept under, while the uncultivated ground around may be covered with it. In connection with this, it is to be remarked that for land plants potash salts are necessary, but it is doubted whether soda salts are essential, except in the case of Salsolæ, &c., which grow in soda soils. This may have something to say to the barrenness of our soda reh soils. Another factor to be noticed is the effect of shade produced by vegetation, which prevents the excessive evaporation which brings the salt to the surface. It thus remains more diffused

through the moisture in the soil. Lastly, plants also induce capillary currents towards themselves. The absorbing parts are the rootlets and myriads of hairs surrounding each. These, by the act of absorption, set up capillary currents in the moisture of the soil towards themselves, which compete with capillary evaporation at the surface and tend to the diffusion of the moisture and its salts through the soil as far as the roots extend. It is to be noted that if a soil remain damp, so that the salts are diffused through it, they may do no harm. It is their concentration as a scum on the surface that poisons crops. The moisture round the rootlets forms a solution so saline that the osmose currents by which the plants are nourished are interfered with and they perish.

27. A very important point materially affecting the question of the cure of reh, is how far reclamation or non-development may be due to diffusion of the salt in the soil. In rainy and damp portions of the plains similar in conditions of subsoil drainage to reh-stricken tracts, we find no efflorescence. How far is this due to surface washing and how far to diffusion? From three experiments made this year, it was found that the rain waters coming off the surface of reh-ground contained a perceptible quantity of the salts. Nevertheless the great fact of occlusion by means of the first soakage portion of the rainfall was proved by the occurrence of a copious efflorescence on the drying of the washed soil. If the rainfall were very copious, would it succeed in washing off excess of salt? This question might be settled by analysis of the total quantities of soluble salt in soils of the rainy and dry tracts of the plains, within the range of surface soakage. As it would be impossible to select two spots precisely similar in conditions of subsoil drainage and constitution of soil, it is evident that no conclusion would be of value except from a great number of experiments.

28. Speaking broadly, the development of efflorescences occurs in India chiefly in a well-marked meteorological area, including the Punjab, except at the base of the hills, similarly the upper part of the North-Western Provinces, and also Sinde and Rajputana. This region is characterised by small rainfall, dryness of the air, and excessive solar heat, each of these as shown contribute to the concentration of salt on the surface. On the other hand, in similar parts of the Indo-Gangetic plain, where there is more copious rainfall, this of itself by keeping the soil moister causes diffusion of any salt present through the soil. Again, the sheet of air which covers the ground contains more moisture and acts in two ways in preventing surface concentration. It diminishes the effect of solar heat, because, as Tyndall has shown, the invisible vapour of water absorbs a great deal of the heat, thus preventing damp regions, such as Lower Bengal, from reaching such high temperatures as the dry regions of Upper India, even though the latter are of higher latitude. In addition, there is more cloud in the damp regions which also abstracts solar radiation, whereas in Upper India the sky is cloudless most of the year. Again, the presence of a moister sheet of air over the ground abstracts evaporation, which takes place in proportion to the dryness of the air. It is very desirable that a series of experiments should be made regarding the total salts occluded in the drier and moister parts of the plains within the ranges of surface soakage and evaporation.

29. As regards the effect of reclamation, further experiments are also required, in order to show how much is due to removal or diffusion of the salts. I estimated the total salt in reclaimed soil and in adjoining reh-ground to the depth of 3 feet at two places near Lahore. Equal columns of earth were taken up by boring with a tube. The result was negative, as in one case the reclaimed soil contained a little less salt than the adjoining reh-ground, and in the others rather more than a third less. No conclusion of any value can be drawn except from a large number of estimates, the variables affecting each case being also taken into account.

30. The state of porosity of the soil has also a great deal to do with the appearance of the efflorescence. Nothing is apparently more capricious than the way it shows itself in one spot of a field and not in another. This may be partly due to difference of constitution of the elements of the soil, but there is no doubt that another cause must be the facility of capillary evaporation due to the variable mixtures of sand and clay of which these alluvial soils are composed. This also suggests a question that might be of importance, as to how far reh soils could be improved by additions of sand or clay so as to affect their capillary action.

Methods of cure.

31. I conclude this paper with some practical remarks regarding the methods of dealing with saline efflorescence agriculturally; but these I wish to be considered suggestive more than any thing else, as I cannot pretend to any experience in that line. When visiting Utah I was very much struck on finding that the saline efflorescences of that basin were similar in nature to those I had seen and studied in India. I made enquiries into the ideas current on the subject and the methods of reclaiming the soils. Brigham Young's notions of natural philosophy were both extremely simple and at the same time shrewd, as would be expected from an uneducated, but practical and successful man. He said: "There is salt in every thing. Water has salt, plants have salt, and earth has salt; and the Bible tells us that if the earth have lost its salt it is useless. A certain quantity of salt is necessary for vegetation; in our country we have too much of it, and we get rid of part of it." He referred me to Mr. Woodruff, who was Secretary to the Agricultural Society, and to some of the best farmers, to see what was done. The plans adopted were the following: A salt field was ploughed and small runlets of fresh water were sent down the field, at short distances apart, washing the soil and running off into the drainage of the country. Another method was to plough up a field and make a terrace round it and then flood it. The water was allowed to soak for some time till it had dissolved the salt and was then run off. Another plan was to terrace a ploughed field and dig a deep trench round it. The field was flooded, and the unploughed subsoil being less permeable, the water holding the salt in solution filtered into the trench. I observed similar processes carried out on the salt marshes round the Bay of San Francisco. This is gradually silting up, and surrounding it are miles of low flats impregnated with sea salt and growing only saline plants. Through these pass shallow delta channels, scoured by the rise and fall of the tide. To reclaim this soil, low earth embankments are raised

By sluicing and irrigation.

round the farms. These are fitted with flood-gates closed by the rise of the tide and opening on its fall. The salt in the soil is washed out by the fresh water of the streams falling into the bay by a process of sluicing such as I have described, and is run off as the tide falls. In the depression between the coast range and the second range of hills artesian wells can be made, and these were used where none of the mountain streams were available. An English Company was working on a salt marsh by the aid of artesian water only; but it was generally considered that it would not be a success, as the amount of artesian water was after all only trifling compared with the area to be reclaimed. The universal opinion in Utah was, that if they once succeeded in covering an alkali field with a crop of any kind, the victory was won. After the land was half cured, they generally covered it with a hardy grass, the most approved being red-top American grass. Beetroot was also said to grow well as an early crop; after that Indian-corn, and other crops by degrees. Tuberous crops grow well in the country, and the potatoes are said to be the best in the world. The last method I shall mention was that employed by Brother Fenton, an energetic Devonshire farmer. It happened to be impossible for him to get fresh water to wash the salt out of his fields, and he tried large quantities of manure—20 to 50 tons per acre. Barn-yard manure was considered the best, and as his great object was to keep the surface from the sun, which drew up the salt, he also used litter to cover it. The first crops he covered the ground with were the red-top grass and oats, and he sowed his crops in September, so that the ground should be covered with vegetation when the alkali would be appearing. As soon as by this means he got his first crop of red Timothy grass, he found he had succeeded. Mr. Fenton complained that after partly curing one field he ruined it by trenching and bringing up a saline subsoil. His idea was that the salt was a sort of perspiration of the earth, and, therefore, mostly on the surface, and that by turning up the subsoil he would get a better soil. In India it is certainly the case that a short distance below the surface less reh is found. It may be different in a closed basin like that of Utah, where the subsoil also may become saturated with salt. Utah city is partly situated on a bench at the base of the Wasatch hills adjoining the plain, and at first the farms surrounding it were made on the ground that was not saline. About one-fourth of the land under cultivation was salt, and three-fourths of this had been cured by sheer cultivation, much in the way I have described in the case of Mr. Fenton's farm. For the other fourth, sluicing and irrigation had been available. The cultivation of saline soils is also carried out in other settlements. In most old-settled countries, and especially in India, agriculturists are very conservative in following the practices of their forefathers. In America, where the population is composed of emigrants from all countries, every man brings the methods used in his own, and all sorts of trials are made and the fittest survives. These are made in a new country under new circumstances, and people are not bound by traditional customs, but are anxious to try whatever succeeds in the hands of others, and also make experiments according to their own ideas. These may be crude, but still a vast number of experiments

By manure and cultivation.

are made,—not isolated ones by a Government, but everywhere generally by the people themselves—and anything that is successful is hailed as a discovery. Some of the methods I have described as used in America may not always be practicable in the plains of India. To run off the saline water requires a slope and lines of natural drainage that may not be available. It might be possible to run off the salt-impregnated water into absorption wells, thus returning the salt to its natural destination, the underground water. It is a law that a well will absorb as much water without raising its level as it would give out without sensibly lowering it. This means has been used in some cases to get rid of liquid sewage, but was found to poison the wells. The plantation of trees is also proved to be a very efficient means of cure. The kikar is well known as capable of flourishing in such soils. They not only assist in moderating excessive evaporation by shade, but they also absorb and remove a certain amount of salt from the soil. As the alkali exists chiefly in the surface soil and in much less amount at a small depth, trees may grow readily where annual crops could not. The latter have their rootlets only in the surface soil, and are poisoned by the excess of salt; while the roots of trees extend deeper into less saline ground; also plants not only consume a portion of the salt, but they prevent its concentration on the surface. A most conclusive experiment made near the Western Jumna Canal by the Irrigation Department is reported by Colonel Fulton. A piece of utterly useless reh land, for which revenue was remitted, was taken up by the Department and planted with kikar trees. These flourished and a very fine crop of doab grass, 2 feet high, came annually up under the trees, and the efflorescence disappeared. The villagers, seeing that the land was improved and fearing it would be alienated by the new settlement, applied for the restoration of both trees and land, and carried their point in the courts of law. A few days after the restoration the wood was sold to a wood merchant and every tree cut down. At present the doab grass is all gone, and the soil is encrusted with salt. Such an experiment made among American farmers would have excited the keenest interest and given rise to numerous trials of the same.

By arboriculture.

32. The method of cure by nitrate of lime as a manure, suggestad by Dr. Brown, would act in two ways. It would partly serve as a manure favouring vegetation, and in addition it would act on the alkaline and magnesian sulphate by double decomposition, producing nitrate of alkali and sulphate of lime, which last is a slightly soluble salt which is not hurtful to vegetation and would not form an efflorescence. Carbonate of soda would be similarly neutralised, but the sodium chloride would remain unaltered. The natives are well acquainted with this use of nitrous efflorescence, which can be distinguished from the sulphate of soda by its moistness due to deliquescence and by the brown colour and by not efflorescing in fine powder. It consists mainly of common salt and nitrates of lime and soda. This production of nitrate is due to the decomposition of nitrogenous animal or vegetable matter, first producing ammonia, which is afterwards oxidised to nitric acid. An essential condition of the nitrification process is the presence of alkaline carbonate, or carbonate of lime, to fix the nitric acid. For example,

Chemical manure.

ordinary dung heaps may produce plentiful supplies of ammonia, but no nitric acid. Indeed, nitric acid, if present, is changed by the reducing action of the decomposing organic matter to ammonia. If wood ashes containing carbonate of potash or lime be mixed with the heap, the acid becomes fixed. Artificial nitre beds, called *nitrières*, or nitre plantations, were first introduced by the chemists of France to supply nitre for gunpowder during the wars of the Revolution, when the ports of France were blockaded by the English and imports prevented. Animal manure is mixed with carbonate of lime and wood ashes and frequently watered with urine, which produces much ammonia. This is cultivated for two or three years. In tropical countries the production of nitrates is more plentiful and rapid. A manure of a valuable quality could probably be made by municipalities or by the zamindars themselves by mixing pounded kankar, or even marly soil, with manure and moistening it frequently during one or two hot seasons. If it were moistened with liquid sewage, which would tend to produce more ammonia, the production would be increased. This artificial production is an exact imitation of what takes place naturally in soils in which nitre is produced. In the Punjab nitrates effloresce near villages where the soil becomes impregnated with animal sewage, which undergoes nitrification in presence of the carbonate of lime and alkaline carbonate in the soil. The most plentiful supply is in the soil on the mounds that indicate the sites of old villages. This is the main source of the manufacture of saltpetre in the Punjab. Similarly, near buffalo ponds and watering-places for cattle, where dung is trodden into the soil, nitrates effloresce and are swept up by the zamindars as manure. A similar process no doubt takes place when a field is well manured with animal refuse. The conditions of the production of nitrate of lime in the soil are present, and this may account to some extent for the reclamation of alkali soils by manuring alone. For this purpose animal manures would be far superior to vegetable. In plants there is comparatively little nitrogenous matter, which alone can generate nitrates or ammonia. In Utah a favourite manure is the refuse of slaughter-houses, which would be capable of supplying large amounts of ammonia and nitrates.

Uses of reh.

33. As regards the uses to which the alkali efflorescence might be put, sulphate of soda can easily be separated by evaporation and forms a useful purgative. It might be possible to utilize those more rich in alkaline sulphate for the manufacture of carbonate of soda for glass or soap work. The average mixture of sodium chloride and sodium sulphate resembles the product of the first step of manufacture of this carbonate, which is done by the addition of sulphuric acid to common salt. By evaporation the sulphate which crystallizes out first in saturated solutions made from efflorescence containing excess of sulphate, can be freed from most of the common salt, and this would resemble the salt cake. The materials for the further reduction, charcoal and lime, would be readily available, the latter from the kankar beds. Certain soils contain carbonate of soda in such quantities that it can readily be separated by the crystallization process. At one time an enquiry was made as to whether the nitre manufacturers defrauded the revenue to any extent by disposing of the alimentary salt left in the refuse saltpetre earth after

extracting the nitre. Samples have from time to time been forwarded to this office, and these were found to contain from 35 to 70 per cent. of common salt. It would certainly be possible and not very difficult to obtain a rather impure alimentary salt by rough crystallization processes, not only from the saltpetre earth, but also from suitable kinds of reh.

THE REH SOILS OF UPPER INDIA, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

For some time I have intended to publish in the Survey Records a notice of the saline efflorescence known as *reh*, which has been, and will continue indefinitely to be, a subject of the gravest concern to those interested in the welfare of North-Western India. The preceding paper, contributed by Mr. Center, removes the only grounds of hesitation in the matter—as to the adequate illustration of the chemical aspects of the case. The facts of this nature already ascertained by myself and others from the area affected were, indeed, sufficient to establish the case before a jury of experts, and it would have been easy to adduce further illustration from analogous conditions elsewhere; but the men who have to deal with the matter practically are very much the reverse of experts, scarcely even believers, and it is of the greatest importance that the most tangible part of the evidence, the hard facts verifiable by the balance, should be set before them from the very ground which they have to treat. This has been done in a very satisfactory manner by Mr. Center. It only remains for me to supplement his paper regarding some points which it touches on but slightly. The question is truly a geological one, as embracing all the conditions of a complex operation now at work in producing a change in the whole region affected. This has been the difficulty throughout—to induce an apprehension of the situation: that the evil to be encountered is not a fixed obstruction of assignable dimensions and position, but the present active array of natural causes bent upon fulfilling the effects due to conditions that have supervened. In such a case our best efforts may be no more than palliative, unless indirectly, by modifying those conditions, we can mitigate the action of the prime causes.

2. From times far earlier than the date of British occupation, there have been large patches of reh-affected ground in various parts of the Upper Provinces. They are known as *usar* (sterile) and *kalar* (saline) land. As the contention sustained in this and the preceding paper is, that this salt (as such) was not an original constituent of the deposits in which it now occurs, it would be interesting to find any mention of the *usar* lands in remote records of those districts; but it is not at all unlikely that some of them may be of very ancient origin, from the historical point of view. What has recently (within the last 30 years) brought the subject into such prominence was the rapid local extension of reh efflorescence in connection with the great irrigation canals that have been constructed in Upper India. Shortly after my arrival at Roorkee (Rurki), then the head-quarters of irrigation, I was consulted about this plague of salts; not, indeed, as a geologist,

but because I dabbled in chemistry. Samples of soils, sub-soils, and waters were sent for examination. The rough results of this work and of such field observations as I could make in the neighbourhood (which was not a reh district) were brought together in a paper for the Asiatic Society, London (Journal, Vol. XX, p. 326, 1863). This paper and a number of official reports on the same subject were published as No. XLII (1864) of the Selections from the Records of the Government of India in the Public Works Department, as "correspondence relating to the deterioration of lands from the presence in the soil of reh." Many other letters and reports, such as that of the Aligarh Committee in 1878, have from time to time been printed for departmental circulation; but the above is the only information that I know of as available for general reference.

3. So early as 1850, in reply to some questions with samples for analysis, Dr. O'Shaughnessy had supplied facts from which an understanding of the whole case might have been evolved: that the canal water is remarkably pure, although containing an appreciable amount of the reh salts; that the sub-soils of reh land are remarkably free from salts; that the reh is accumulated in the surface soil; and he pointed out that a free use of canal water, with efficient drainage, would certainly cure the evil (*l. c.*, p. 36). No suggestion was, however, made as to how the reh came there: so on this score full play was left for fancy to suit the bias of the speculator. Accordingly, the final decision passed upon these facts by the Board of Revenue is recorded as follows (*l. c.*, p. 8):—"There is, then, positive scientific evidence that the canal water is perfectly pure, and the idea, though it has been started more than once, cannot be entertained for a moment that the salts are deposited by the water used in irrigation. When *reh* appears, it must be that it has previously existed in the soil. For in no lands is the efflorescence of *reh* so extensive or so rank as in those large spaces so common in all the villages of Paneeput and Soonput, where the plough has never been driven; where seed has never been cast; and which, under the name of *kullur* (answering to the *oosur* of the midland districts), were excluded from the malgoozaree area, for the express reason that they were barren, or, in other words, had too much saline matter in their soil to admit of their being cultivated." This judgment gives a fair illustration of a mischief that too often occurs in India; as must happen where the higher administration is in the hands of men who have grown into it, after a long training in a narrow but very real school of virtual omnipotence, resulting in impenetrable self-confidence; and who consequently never hesitate to undertake and pass decisions upon matters where they are quite unqualified to hold an opinion.

4. Finding that in this matter the local fancy was without rational bounds, and the bias strong in a false direction, I set myself (in the paper referred to) to trace the source of the reh; I pointed out (*l. c.*, p. 40) how the supposition of any store of reh in the ground was untenable, except of course when reh-water had lodged in the upper water table; I proved a case (*l. c.*, p. 43) in which a reh soil had been produced by accumulation from a source no more abundant than the canal water; I stated my conviction (*l. c.*, p. 45) that the old *usar* or *kalar* lands were only special areas of inefficient drainage, lands more or less dependent on evaporation for the removal of surface waters; that, in fact, the

whole phenomenon of reh was superficial, due to the inefficient circulation of the atmospheric waters under extreme climatal conditions.

5. The foregoing brief remarks must suffice as a historical summary of the reh question. We may now, perhaps, assume that the rational explanation of the situation is accepted, or must become so; and proceed to form an estimate of its conditions. My remarks here also must be condensed, referring only to the leading features; a fuller discussion of some particulars was given in my reports to the Aligarh Committee of 1878.

6. The only points to which I need take exception in the views set forth in the preceding paper, are those from which it might be inferred that the state of things so much to be deplored—no less, in fact, than the steadily-advancing conversion of the choicest lands of India into a howling wilderness, such as now obtains over the once luxuriant Mesopotamia—that this is inevitable from natural causes. I have pointed out these weak points to Mr. Center, and he has permitted me to explain them, rather than undertake to do it himself:—It is correctly stated that under certain conditions of surface configuration, of ground structure, and of climate, the local accumulation of saline deposits must take place; the instances given are the great land-locked basins of central North America and Asia. The first condition may be ignored, as it is immaterial whether the surplus waters are concentrated in a local basin or added to the briny deep.

7. The second condition is important. In several passages of paras. 14, 21, and 24 of Mr. Center's paper, the strata forming the plains are described as horizontal, so that the conditions of drainage approach those of a basin, the underground drainage being usually imperceptible. These features of the bhángar land are contrasted (para. 24) with those of the khádar land, where "the river occupies the line of natural drainage of the country, and its deposits are parallel to the line of slope," underground drainage taking place freely; and this, although the khádar valley is truly described as cut out by recent erosion from the old alluvial plain. The small apparent contradiction here is easily explained: the ground surface in the khádar is almost always of very recent sandy deposits, the surface of actual erosion being confined to the present river channel; but there is a real and greater misconception which it is needful to insist upon. It is not questioned that the plains themselves are river deposits; their surface, too, lies appreciably parallel to that of the actual river beds throughout; so it is not intelligible how the lie, or the composition of the strata, can be supposed so different from those of the actual rivers. In the process of land formation by rivers, of which the plains of India afford such a striking example, there does occur partially the production of local basins. From the diluvial zone, where the torrents are discharged from the mountains, to the more exclusively alluvial region of the delta, a partial sorting process takes place in the river deposits. The coarser materials, which in the former position are boulders and gravel, and in the latter fine sand, become thrown down wherever the velocity is checked and along the margin of overflow, thus forming the banks between which the river flows, whether in a single channel or through several distributaries, often at a higher level than adjoining ground separating the channels. These intra-fluvial areas become for the time swamps or temporary lakes in

which some deposition of finer sediments occurs more or less in basin fashion; but they principally become filled up by the invasion of the river to find a lower level; when, at least on the line of the new channels, there must be considerable removal and ultimate replacement of any finer sediments. In this way it seems probable that in the growth of the river plains, it is rare for any large area to escape being traversed by a channel of considerable magnitude, or for such areas to be filled up by deposits in which the slope of the river itself is not on the whole maintained. The original *usar* plains may have been such exceptional areas, in which therefore special local obstruction existed to underground drainage. It must, indeed, be admitted that the actual subsoil drainage of the plains is usually imperceptible; but this seems to be directly accounted for by what is the head and front of the complaint regarding reh: that owing to shallow cultivation, to the sun-baked condition of the surface, and to the absence of any considerable tree vegetation, the rainfall can only soak to a small depth, the remainder running to waste off the surface, or being taken up again by evaporation. For efficient drainage there must be efficient penetration to supply it withal: and, deficient percolation of water through the soil and the sub-soil to the ground beneath is the condition, in default of which the growth of reh is inevitable. It would, of course, be easy to imagine circumstances more favourable to drainage than are those of the gently-sloping alluvial deposits of these plains; but it seems to me that reh being in part a necessity of the ground structure here, cannot be sustained.

8. There remains the condition of climate, which is the active element of the combination. It is represented (para. 15) as being analogous to that of the typical cases cited, only intensified by heat. Here, again, I have to admit the actuality, but as a charge against nature it is even more untenable than the last. There is contrast rather than correspondence between the physical surroundings of India and those of the typically arid tracts mentioned. In these, aridity is indeed more or less inevitable, for the life-giving moisture hardly approaches them, being to a great extent abstracted from the air currents before they reach these areas. But India is on two sides bounded by a reeking caldron of tropical ocean; and on the third there is a great air-elevator, flanked by a huge condenser, sending back upon her plains almost every drop of the water that had previously floated over them, repelled to a very large extent by the accumulated heat of the bare and parched ground surface. The endeavour to make these returning waters do duty for rainfall must be a very poor substitute for the due reception and conservation of them in this form in the first instance. It can scarcely be questioned, that left to nature, every foot of our Indian deserts would now have been covered with perennial verdure, and that the present desolation is the result of the devastating proclivities of a worse than savage mankind. It may, too, be affirmed that with time the blessings of nature might be restored.

NOTE ON THE NAINI TAL LANDSLIP (18TH SEPTEMBER 1880), *by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

On Saturday, the 18th of September, at half past one in the afternoon, after more than thirty-six hours of heavy continuous rain, a portion of the hill forming the north-east slope of the valley of Naini Tal fell, sweeping away several houses, and causing the death of 43 Europeans and more than 150 Natives.

Briefly told, the story of the slip is this: On the morning of the 18th, at ten o'clock, a small slip occurred behind the Victoria Hotel, burying part of the buildings in which were some Natives and an European child. A party of volunteers and a working-party from the depôt were soon on the spot, but after a while the greater portion of the latter were withdrawn. After rescuing all that there seemed any probability were still alive, they found that the house was in danger of being washed away by a stream of water, and so turned their attention to the diversion of the stream; and while engaged in this, the great slip came down and overwhelmed them. It is possible that the wash of this diverted stream may have directly contributed to bringing down the landslip, but it seems to me very improbable that it had any such effect; at most it can but have hastened the catastrophe by a few hours.

The part of the hill which has fallen extends up to the old Government House, marked as such on the map. From here the western boundary runs down a little to the east of Marshal Cottage and Charlton; the eastern boundary passes down just to the east of the Victoria Hotel. The mass of debris which has fallen from the hill extends over the level ground at the head of the lake, as far as the Assembly Rooms, of which but the southern end remains standing.

The slip, as it at present stands, stretches in a long, gentle slope, which, omitting irregularities of surface, is not more than 15° up to where the old Victoria Hotel stood; from there it rises in a steep slope of 25° or so, and at the top comes a short space nearly vertical. This steep slope is formed by the small slopes of drier debris which fell after the great one. The total length of the slip, measured horizontally, is about 600 yards, of which over 300 are occupied by the gentle slope, and the remainder are more or less steep.

The hill on the north-east of the lake consists of more or less imperfectly-cleaved clay slates, occasionally showing signs of an initial metamorphism into schist, but for the most part a simple clay slate. The dip is very disturbed, and varies much in different parts in close proximity to each other; but the general dip is to the south-west. The rock also is traversed by very numerous joint planes, which cause it to split up into innumerable fragments under the action of the weather.

Although the whole of the ridge bounding the Naini Tal valley on the north-east is practically one as regards its internal structure, yet, superficially, the south-east portion is very different from the north-west. Looking from the head of the lake, or, still better, from near the old Government House, one cannot fail to be struck by the difference of profile; towards the lower end of the lake the hill sweeps down at an even slope of about 25° from almost the top down to the level of the lake, while nearer the spot where the landslip took place there is a peculiar

bulged appearance of the hill, which makes the slope steeper near the bottom than it is higher up, being occasionally, as above the mission premises, as steep as 35°.

These two areas can be recognised on the map; the even slope near the lower end of the lake is drained by innumerable channels running almost straight down the hill, while on the bulged portion the streams are fewer and their courses not nearly so directly down the hill.

The cause of this bulged appearance I take to be as follows: By the action of the weather the face of the hill gets covered with a greater or less thickness of decomposed rock, which, as already explained, weathers into a mass of small fragments. The rain water, which obtains access to the interior of the hill, for the most part keeps in this decomposed layer and flows down at a short distance from the surface, passing out again lower down in the springs which exist in numbers over this hill, and a large part doubtless percolating downwards reaches the lake without coming to the surface. The presence of large quantities of water among this decomposed rock must, by making it more mobile, assist in producing that phenomenon which is seen in any mass of debris lying at a slope, whether it be wet or dry, namely, the gradual passage of such debris down the slope under the influence of gravity; that some movement of the debris down the slope takes place after heavy rains, seems certain, as is shown by cracks appearing in the surface of the hill side, the lower side of which subsides slightly. Now on a level surface the action of gravity can have no effect in producing any motion, while on a slope the force tending to produce such motion varies directly as the resultant of the vertical force of gravity acting directly down the slope, that is, it varies as the sine of the angle of inclination. Suppose, then, an even slope passing near its base into level ground, and that slope covered with debris; the debris slides slowly down the hill, but on the steeper parts of the slope it must do so faster than near the bottom, where the slope is less and there is the resistance of the debris lying on the level to be overcome, which can only be done by a *vis a tergo*, an impulse from behind. The debris coming slowly down from above and meeting with this obstacle gradually accumulates till it causes a bulging of the slope towards its base, which goes on increasing till the lower part of the hill is so steep that, to use a colloquial phrase, "it is touch and go" whether the hill can stand or not; then a burst of rain heavier than usual comes, the head of water is increased, the force of the water flowing out near the bottom is increased, it begins to wash away the debris near the bottom till the support being removed from below small slips begin to fall; then a few larger, and finally comes the great slip, which brings down the outer crust of half the hill side, leaving a precipitous border round that part from which it has come; finally, the great slip is followed by smaller ones, which leave the hill with a pretty uniform slope from top to bottom for the whole process to begin again. Such I believe to be the history of one of these landslips where there is no stream cutting at the base of the hill; where that is the case, slips may be formed at any time by the cutting away of the foot of the slope.

The slip under consideration has followed very much the course pointed out; the bulging had reached the critical point: all through last rains small slips

occurred; on the 18th a larger one fell, shortly to be followed by the great landslip, which was itself followed by one or two minor ones, though the process of smoothing down the slope has not yet been completed.

Applying this hypothesis to the determination of the question of how much of this same ridge must be pronounced as unsafe and liable to slippage, we must condemn the hill side from a line running upwards from the bank-house to a similar line running down from a little to west of Fairlight Hall, it being all more or less bulged; of this, that part extending from the old landslip to the stream flowing down to the east of the Mission premises must fall in a few more years, but, with this exception, a judicious systém of revetment of the torrent beds and a complete system of drainage of the cleared sites will do much to prolong the existence of the present hill side.

As regards the slopes below Chína, there is but little chance of such a slip taking place; these slopes are the talus of the steep scarp of Chína, and are continually receiving additions from above, and though on them there may be danger from the large boulders which occasionally fall from Chína, the slopes pass off so gently into the comparatively level ground at the head of the lake, and are moreover concave rather than convex in profile, that I consider the probability of any of them forming a large slip to be very small indeed.

Many interesting points might doubtless be elicited as to the manner in which the mass moved, were there any satisfactory accounts of eye-witnesses; but such there are not, and for the same reason that it is almost impossible to get a trustworthy account of a great earthquake,—the thing is so sudden and so awful that none but trained observers can keep their presence of mind necessary for making those exact observations which only can be of any scientific use.

The only points which can be satisfactorily established are, that the whole fall must have been over in less than quarter of a minute, and that the Victoria Hotel and Bell's Shop (Racquet Court) were carried along some distance before they fell; in the latter case there is proof of the fact, inasmuch as the ruins are now some yards from the spot on which the building originally stood. As the ground on which both these buildings stood consisted entirely of debris, locally known as 'shale,' which must have been saturated with water after the heavy rains which for thirty hours and more had been pouring into it, it is not surprising that when the wreck of the hill side was precipitated on to it, it should yield as a semi-fluid body would do and float the buildings for some little distance before the actual slip overtook and overwhelmed them. That the whole mass must have been in a semi-fluid state from the amount of water contained in its substance, is shown by the low angle at which it now lies, and by the fact that those who ventured on to the fallen mass immediately after its fall sank up to their knees in the slush, as it has been described.

Doubtless, the point of most scientific interest in connection with this landslip is its bearing on the theory of lake formation by landslips. One of the principal objections raised to the supposition that the barrier at the outlet of Naini Tal, for instance, can be formed by a landslip is, that those slips "possessed of most mobility, from the greater fluidity of their composition, are in the

precise ratio of such fluidity least capable of * * bearing upon their surface craggy masses of rock, such as I should term erratics" (*supra*, p. 165). The examination of the landslip under consideration disposes of this objection; for though most certainly such 'craggy masses of rock' were not born on the surface of the semi-liquid mass, yet there were numbers such floated in its substance, many of which now show at the surface, several being 9 or 10 feet in length exposed; and I have no hesitation in saying that were this landslip on a larger scale—for it must not be forgotten that compared with several others in the hills around it is insignificant in size—and left untouched by the hand of man, it would, when cut into by rain and streams, show many if not all those features which are supposed to be especially characteristic of a moraine.

As to the question whether the barrier of the Naini Tal basin is a landslip or a moraine, I shall not here enter into its discussion; this, however, I must say, that the profile of the slope to the east of the outlet bears every appearance indicative of a large landslip having fallen there. On the hill side there is no bulging, but a straight sweep down to a comparatively level terrace, through which the stream forming the outlet of the lake has cut down for some distance. Whether the lake was formed by the landslip, or whether this was subsequent to the formation of the lake, I am not prepared to assert dogmatically; but this I believe, that in past times there has been a great landslip from the slopes of the Kalikhan, and that on this old slip are placed the hospital and convalescent depôt.

The recent slip shows clearly that a large landslip can extend across and fill up a valley, and at the same time may show that mixture of rocks of all sizes which forms one of the chief features of a moraine; and it is not improbable that, under favourable circumstances, it might resist the wash of a stream over it and so form a permanent lake. In the case of Mulwa Tal, one would certainly suppose from the look of the ground that if its existence is not due to a landslip, yet the level of the water must at one time have been raised some twenty or thirty feet higher than it now stands, by a great landslip which has undoubtedly fallen from the hills to the east of the outlet in times which may not date further back than one or two hundred years, and are certainly later than much that geologists would speak of as recent.

But if a lake is to be formed by a landslip, it must not merely be one of those which are everywhere to be seen, caused by the cuttings of a stream into the base of the slope, but rather one of those which take many years and even centuries preparing, as has been the case with this small one at Naini Tal, and which when they fall do not come down in a stream of fragments, but with one great rush, which would carry them right across the valley and raise the surface to such a height that, by the time the dammed-up water reached high enough to overflow, the debris would have had time for the water mixed with it to drain off somewhat, and would have settled down sufficiently to withstand the wash of the stream running over it. Such cases have been known, but the dam has always given way; yet it is not inconceivable that in some cases which have happened in that remote past, of which we have no knowledge but what is written in the rocks, some few barriers so made were able to stand and form what are now known as the Kumaun lakes.

Yet it must always be kept in mind that no theory which can be put forward to account for their formation can be considered satisfactory, unless it also accounts for the absence of similar lakes in other parts of the Himalayas; for it is no explanation to say that this is due to the smallness of the drainage areas which supply the lakes, and the consequent small size of the streams flowing from them, for other portions of the Himalaya are not devoid of small streams, nor can that which flows from Mulwa Tal be called small.

NOTE.

My youngest colleague, Mr. Richard D. Oldham, happening to be in Kumaun at the time, I asked him to give me an account of the disastrous landslip at Naini Tal. The foregoing excellent paper is the result. It is Mr. Oldham's first contribution to the publications of the Survey; and the accurate observation, strict reasoning, and good form it evinces, give high promise of fruitful work to come.

It will not be amiss, on an occasion of such vital interest, to add a few remarks that occur to me, especially as suggested by the report of the Committee appointed by the Local Government to enquire into the condition of the Sherka-danda hill, a copy of which was sent to me officially at about the same time, 'for information.' The portion of the hill marked by the Committee as presently dangerous corresponds very nearly with that indicated by Mr. Oldham; but their observations would seem to have a wider extension, and to involve a larger area of affected ground. Mr. Oldham was only there for a few days, on his way to take up work for the season in Sirmur, and he probably confined his attention to the particulars of the event under discussion. I did not instruct, or expect, him to do more than he has done, the Survey not having been called upon for an examination of the ground.

It would be understood from the report of the Committee that the surface cracks, justly regarded as symptomatic of failing ground, occur much beyond the area condemned, also the Committee's description of the geological structure of the hill would be taken in the same sense; it is as follows:—"To the ordinary observer the hill seems to consist of a core of rocky shale, the dip of the strata being to the south-west, at an angle varying from 30° to 50°. This core is covered by varying thicknesses of disintegrated shale and mud, in which are scattered boulders of limestone, and occasionally of trap, the whole of this crust being in its natural state bound together by a luxuriant growth of grasses, shrubs, and trees." It does not appear that this is thought an unusual composition for the crest of a steep ridge, 7,000 feet in elevation. As applied to the dangerous ground, it would exactly suit the conditions described by Mr. Oldham—the decomposed clay-slate creeping down the hill side, carrying with it blocks detached from the occasional outcrops of harder rocks. It is scarcely possible under the circumstances that such a crust could be rock *in situ*, whether an enveloping shell of some unconformable deposit, or a condition, however decomposed, of the rocks described as the 'core.' It can, in such a position, only have been formed from these latter by displacement, being either the remains of an old landslip, or the material in order of active preparation for a slip to come. In the former case the ground may be perfectly safe, in the latter it would be at least doubtful. If, then, this description applies extensively, as might be inferred from the Committee's report, the matter may be worth further consideration; for the premonitory 'bulging,' so effectively detected and described by Mr. Oldham, may not be a necessary part of the performance. In the case of the condemned area, that feature is reasonably ascribed to the resistance so well presented at the base, where the slope tails off into the flat ground at the head of the lake; but where this condition does not obtain, as along the lake shore to the south-east, a crisis might occur without that visible warning, although there would be every reason to expect it to be mild in comparison to what happens when an accumulation has occurred by bulging.

Altogether, it is by no means unreasonable to hope that the practical judgment of the Com-

mittee may be well founded—that, except in the proscribed ground, security can be insured by proper precautionary measures. Mr. Oldham has expressed the same opinion.

In the 30th September number of *Nature, a-propos* of the Naini Tal catastrophe, there is a picturesque description of landslips in general. The writer is evidently thoroughly informed upon the subject he treats of, although grievously in error regarding the geological condition of Naini Tal, which is described as on the tertiary rocks. This mistake is unaccountable; for the place is clearly shown on our geological sketch-map of India as inside the Sub-Himalayan boundary. From the foregoing notice it will be plain that the Naini Tal slip cannot be classed with any of the particular cases mentioned in *Nature*. I have seen no fact to suggest that there is any predisposing plane of stratification connected with these slips. The contrary may, indeed, be affirmed; for although the general dip of the strata is stated to be south-westerly, the frequent contortion these slates have undergone almost forbids the supposition of a continuous surface of any extent in a fixed direction, such as is implied by the action in question.

The Naini Tal landslip of the 18th September was in fact, except on the score of mischief, a comparatively small affair, considerably less in magnitude, as mentioned in Mr. Oldham's paper than several others that occurred at the same time in the Kumaun hills.

H. B. MEDLICOTT.

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